UNIVERSITY OF ARIZONA
39001032378690

Physical Properties of Hydrocarbons

And Other Chemicals

VOLUME 3

R. W. GALLANT
CARL L. YAWS

Digitized by the Internet Archive
in 2024

https://archive.org/details/physicalproperti0003gall

Physical Properties of Hydrocarbons
And Other Chemicals

VOLUME 3

Gulf Publishing Company
Houston, London, Paris, Zurich, Tokyo

QD
305
H5
G28
v.3
Sci Ref.

Physical Properties of Hydrocarbons
And Other Chemicals

VOLUME 3

R.W. GALLANT
CARL L. YAWS

Physical Properties of Hydrocarbons
Volume 3

Copyright © 1993 by Gulf Publishing Company, Houston, Texas. All rights reserved. Printed in the United States of America. This book, or parts thereof, may not be reproduced in any form without permission of the publishers.

Gulf Publishing Company
Book Division
P.O. Box 2608, Houston, Texas 77252-2608

10 9 8 7 6 5 4 3 2 1

Printed on Acid-Free Paper (∞)

Library of Congress Cataloging-in-Publication Data
(Revised for vol. 3)
Gallant, Robert W.
Physical properties of hydrocarbons.
1. Hydrocarbons—Tables. I. Title.
QD305.H5G28 1993 547'.01 92-45600
ISBN 0-88415-175-1 (v. 2)
ISBN 0-88415-176X (v. 3)

CONTENTS

Chapter Page

1. CARBON OXIDES 1
2. NITROGEN AND OXYGEN 14
3. AIR 23
4. OZONE 32
5. AMMONIA 42
6. HYDROGEN AND HELIUM 52
7. ARGON AND NEON 61
8. NITROGEN OXIDES 70
9. SULFUR OXIDES 80
10. HYDROGEN AND CARBONYL SULFIDES 90
11. HYDROGEN HALIDES 100
12. HALOGENS 110
13. C_{10}, C_{12} AND C_{14} NORMAL ALKANES 119
14. C_{16}, C_{18} AND C_{20} NORMAL ALKANES 129
15. C_{10}, C_{12} AND C_{14} ALPHA ALKENES 139
16. C_{16}, C_{18} AND C_{20} ALPHA ALKENES 149
17. C_1 TO C_3 NORMAL ALKYL CYCLOPENTANES 159
18. C_1 TO C_3 NORMAL ALKYL CYCLOHEXANES 169
19. C_4 TO C_6 NORMAL ALKYL BENZENES 179
20. C_7 TO C_9 NORMAL ALKYL BENZENES 189
21. C_{10} TO C_{12} NORMAL ALKYL BENZENES 199
22. NAPHTHALENE AND DECAHYDRONAPHTHELENES 209

REFERENCES 219

Appendix

A. CONVERSION TABLES 225

B. COMPOUND INDEX BY FORMULA 226

C. COMPOUND INDEX BY NAME 231

PREFACE

The objective of PHYSICAL PROPERTIES OF HYDROCARBONS AND CHEMICALS, Volume 3, is to provide the working engineer with all the essential data to design and run production facilities. The data are presented in graphs covering a wide temperature range to enable the engineer to quickly determine the information he needs at the desired temperature.

The literature has been carefully searched for experimental data. When several sources give different values, the authors made a judgment as to the most reliable source. To enable the engineer to go back to the original article for additional information, the sources of all data are documented.

For many compounds, experimental results are available only over a narrow temperature span. In these cases, estimation methods have been used to extend the data over a wider temperature range. When estimation methods are used, the method and expected accuracy are explained. Thus, the user is aware of the reliability of the graphical values. Reference to the original work is provided for those wishing to study the method further.

The physical properties normally needed in design and production are vapor pressure, heat of vaporization, density, surface tension, heat capacity and thermal conductivity. For chemical reactions, enthalpy of formation and Gibb's free energy of formation are helpful. Also, the boiling point, freezing point, molecular weight, critical properties, lower explosion limit in air and solubility in water are tabulated for each compound. This latter property data are helpful in safety and environmental engineering.

Special attention is paid to improving the accuracy of estimation techniques. Improved methods of extending data and new experimental data are included.

The SI and metric units are used for all properties except vapor pressure, both because these units are becoming increasingly used in production plants and because conversion is generally easier. Each graph displays a conversion factor providing English units. The temperature scale in all graphs is Centigrade.

Robert W. Gallant
Freeport, Texas

Carl L. Yaws
Beaumont, Texas

DISCLAIMER

This handbook presents a variety of thermodynamic and physical property data. It is incumbent upon the user to exercise judgment in the use of the data. The authors and publisher do not provide any guarantee, express or implied, with regard to the general or specific applicability of the data, the range of errors that may be associated with any of the data, or the appropriateness of using any of the data in any subsequent calculation, design or decision process. The authors and publisher accept no responsibility for damages, if any, suffered by any reader or user of this handbook as a result of decisions made or actions taken on information contained herein.

ACKNOWLEDGMENTS

Many colleagues and students have made contributions and helpful comments over the years. We are grateful to each: Jack R. Hopper, Joe W. Miller, Jr., C. S. Fang, K. Y. Li, Keith C. Hansen, Daniel H. Chen, P. Y. Chiang, H. C. Yang, Xiang Pan and Xiaoyan Lin.

The author wishes to acknowledge that the Gulf Coast Hazardous Substance Research Center provided partial support to this work.

A special appreciation is expressed to Carl Yaws' wife (Annette) and family (Kent, Michele and Chelsea; Lindsay, Rebecca, Matthew, and Sarah).

CONTRIBUTORS

Robert W. Gallant	Vice President, Texas Operations, Dow Chemical Company, Freeport, Texas 77641, U S A
Guy E. Fortier	Chemical Engineer, Radian Corporation, Research Triangle Park, North Carolina, 27709, U S A
Jack R. Hopper	Professor and Chair, Chemical Engineering Department, Lamar University, Beaumont, Texas 77710, U S A
K. Y. Li	Professor, Chemical Engineering Department, Lamar University, Beaumont, Texas 77710, U S A
Xiaoyan Lin	Graduate Student, Chemical Engineering Department, Lamar University, Beaumont, Texas 77710, U S A
Randy J. McDonald	Environmental Engineer, United States Environmental Protection Agency (US EPA), Research Triangle Park, North Carolina, 27711, U S A
William E. Simon	Professor and Chair, Mechanical Engineering Department, Lamar University, Beaumont, Texas 77710, U S A
Carl L. Yaws	Professor, Chemical Engineering Department, Lamar University, Beaumont, Texas 77710, U S A

Physical Properties of Hydrocarbons
And Other Chemicals

VOLUME 3

Chapter 1

CARBON OXIDES

Robert W. Gallant, Carl L. Yaws and Guy E. Fortier

PHYSICAL PROPERTIES - Table 1-1

Physical, thermodynamic and transport property data from the literature (1-65,192,193) are given in Table 1-1 for carbon monoxide and dioxide. Results from the DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data such as acentric factor, enthalpy of formation, lower explosion limit in air and solubility in water are also available. The property data in the top and middle parts of the tabulation are helpful in process engineering. The property data in the lower part of the tabulation are helpful in safety and environmental engineering.

VAPOR PRESSURE - Figure 1-1

Results from the DIPPR project (5) were selected. These results are applicable for vapor pressure from very low temperatures to the critical point. Correlation of vapor pressure as a function of temperature was accomplished using the equation:

$$\ln P = A + B/T + C \ln T + D T^E \tag{1-1}$$

where P = vapor pressure
T = temperature

Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 1-2

Results from the data compilation of Yaws and co-workers (44,52) were selected. Data for heat of vaporization were correlated using the Watson equation:

$$\Delta H_{vap} = A\,(1 - T_r)^{0.38} \tag{1-2}$$

where ΔH_{vap} = heat of vaporization
T_r = reduced temperature, T/T_C

Reliability of results is good with errors of about 5% or less.

For the DIPPR project (5), data for heat of vaporization were correlated using a modified Watson equation with extended terms in the exponent:

$$\Delta H_{vap} = A\,(1 - T_r)^{[B + C\,T_r + D\,T_r^2 + E\,T_r^3]} \tag{1-2a}$$

LIQUID DENSITY - Figure 1-3

Results from the data compilation of Yaws and co-workers (44,54) were selected. A modified Rackett equation was used for correlation of the data:

$$\rho = A\,B^{-(1 - T_r)^{2/7}} \tag{1-3}$$

where ρ = saturated liquid density
T_r = reduced temperature, T/T_C

Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

For the DIPPR project (5), a slightly different Rackett equation was used for correlation of the data:

$$\rho = A\,B^{-(1 - T/C)^{D}} \tag{1-3a}$$

SURFACE TENSION - Figure 1-4

Results from the data compilation of Yaws and co-workers (44,55) were selected. Using data from the literature, surface tension over the full liquid range was achieved by the modified Othmer equation:

$$\sigma = A\,(1 - T_r)^{11/9} \tag{1-4}$$

where σ = surface tension
T_r = reduced temperature, T/T_C

Accuracy is good with errors being about 10% or less in most cases.

For the DIPPR project (5), surface tension was correlated by a slightly different Othmer equation:

$$\sigma = A\,(1 - T_r)^{[B + C\,T_r + D\,T_r^2 + E\,T_r^3]} \tag{1-4a}$$

HEAT CAPACITY - Figures 1-5 and 1-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature:

$$C_P = A + B\,T + C\,T^2 + D\,T^3 \tag{1-5}$$

where C_P = heat capacity of ideal gas
T = temperature

Results are in favorable agreement with data. Errors are about 1% or less in most cases.

For the DIPPR project (5), two different equations were used for correlation of the data for heat capacity of ideal gas:

$$C_P = A + B \exp[-C/T^D] \tag{1-5a}$$

$$C_P = A + B\,[(C/T)/\sinh(C/T)]^2 + D\,[(E/T)/\cosh(E/T)]^2 \tag{1-5b}$$

Results from the DIPPR project (5) were selected for heat capacity of liquid. Data were correlated with a series expansion in temperature:

$$C_P = A + B\,T + C\,T^2 + D\,T^3 + E\,T^4 \tag{1-6}$$

where C_P = heat capacity of liquid
T = temperature

Results are in favorable agreement with data. Errors are about 3% or less using the equation. To provide wider coverage, the temperature range was extended using thermodynamic principles.

For the data compilation of Yaws and co-workers (44,59), the following equation was used for heat capacity of liquid:

$$C_P = A + B\,T + C\,T^2 \tag{1-6a}$$

VISCOSITY - Figures 1-7 and 1-8

Results from the DIPPR project (5) were selected for viscosity of gas. Data were correlated using the equation:

$$\eta_{gas} = \frac{A\,T^B}{1 + C/T + D/T^2} \tag{1-7}$$

where η_{gas} = viscosity of gas
T = temperature

Results are in favorable agreement with data. Errors are about 5% or less in most cases.

For the data compilation of Yaws and co-workers (31), a series expansion in temperature was used for viscosity of gas:

$$\eta_{gas} = A + B\,T + C\,T^2 \tag{1-7a}$$

Results from the DIPPR project (5) were selected for viscosity of liquid. Data were correlated using the de Guzman - Andrade equation with extended terms:

$$\ln \eta_{liq} = A + B/T + C \ln T + D\,T^{E} \qquad (1\text{-}8)$$

where η_{liq} = viscosity of liquid
T = temperature

Correlation results and data are in favorable agreement with errors being about 10% or less.

For the data compilation of Yaws and co-workers (31), a modified de Guzman - Andrade equation was used for viscosity of liquid:

$$\log \eta_{liq} = A + B/T + C\,T + D\,T^2 \qquad (1\text{-}8a)$$

THERMAL CONDUCTIVITY - Figures 1-9 and 1-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data were correlated using the equation:

$$\lambda_{gas} = \frac{A\,T^{B}}{1 + C/T + D/T^2} \qquad (1\text{-}9)$$

where λ_{gas} = thermal conductivity of gas
T = temperature

Reliability of results is good with errors of about 10% or less in most cases.

For the data compilation of Yaws and co-workers (31), a series expansion in temperature was used for thermal conductivity of gas:

$$\lambda_{gas} = A + B\,T + C\,T^2 + D\,T^3 \qquad (1\text{-}9a)$$

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. Data were correlated using the equation:

$$\lambda_{liq} = A + B\,T + C\,T^2 + D\,T^3 + E\,T^4 \qquad (1\text{-}10)$$

where λ_{liq} = thermal conductivity of liquid
T = temperature

Results are in favorable agreement with data. Errors are about 3% or less in most cases.

For the data compilation of Yaws and co-workers (31), a series expansion with less terms was used for thermal conductivity of liquid:

$$\lambda_{liq} = A + B\,T + C\,T^2 \qquad (1\text{-}10a)$$

ENTHALPY OF FORMATION - Figure 1-11

Results from the data compilation of Yaws and co-workers (44,45) were selected. Data for enthalpy of formation of the ideal gas is a series expansion in temperature:

$$\Delta H_f = A + B\,T + C\,T^2 \tag{1-11}$$

where ΔH_f = enthalpy of formation of ideal gas
T = temperature

Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 1-12

Results from the data compilation of Yaws and co-workers (44,46) were selected. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature:

$$\Delta G_f = A + B\,T + C\,T^2 \tag{1-12}$$

where ΔH_f = Gibb's free energy of formation of the ideal gas
T = temperature

Results from the correlation are in favorable agreement with data.

CORRELATION CONSTANTS FOR EQUATIONS

The A, B, C, D and E in the above equations are correlation constants for the specific property under discussion. The correlation constants which have distinct values for individual compounds maybe used in the above equations to calculate the specific property value at the temperature of interest.

Table 1-1 Physical Properties

1. Name	Carbon Monoxide	Carbon Dioxide
2. Formula	CO	CO2
3. Molecular Weight, g/mol	28.010	44.010
4. Critical Temperature, K	132.92	304.19
5. Critical Pressure, bar	34.988	73.815
6. Critical Volume, ml/mol	93.10	94.00
7. Critical Compressibility Factor	0.295	0.274
8. Acentric Factor	0.0663	0.2276
9. Melting Point, K	68.15	216.58
10. Boiling Point @ 1 atm, K	81.70	194.67 (sublimation)
11. Heat of Vaporization @ BP, kJ/kg	215.55	------
12. Density of Liquid @ 25 C, g/ml	------	0.711
13. Surface Tension @ 25 C, dynes/cm	------	0.588
14. Heat Capacity of Gas @ 25 C, J/g K	1.041	0.844
15. Heat Capacity of Liquid @ 25 C, J/g K	------	5.000
16. Viscosity of Gas @ 25 C, micropoise	176.78	149.70
17. Viscosity of Liquid @ 25 C, centipoise	------	0.064
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0251	0.0165
19. Thermal Conductivity of Liquid @ 25 C, W/m K	------	0.0763
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-110.48	-393.50
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	-137.26	-394.38
22. Flash Point, K	------	------
23. Autoignition Temperature, K	882.04	------
24. Lower Explosion Limit in Air, vol %	12.5	------
25. Upper Explosion Limit in Air, vol %	74.0	------
26. Solubility in Water @ 25 C, ppm(wt)	23.77	1,950

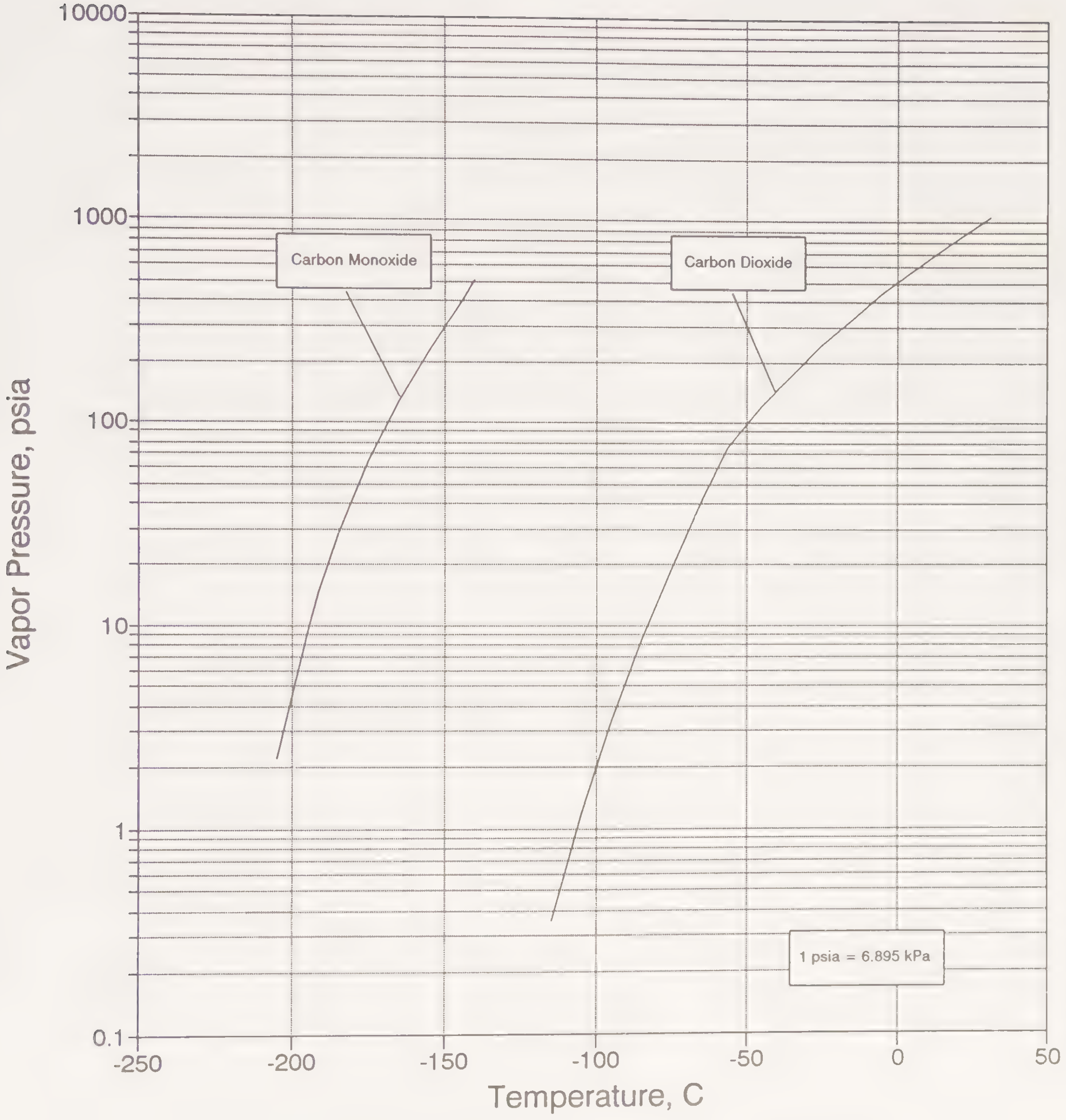

Figure 1-1 Vapor Pressure

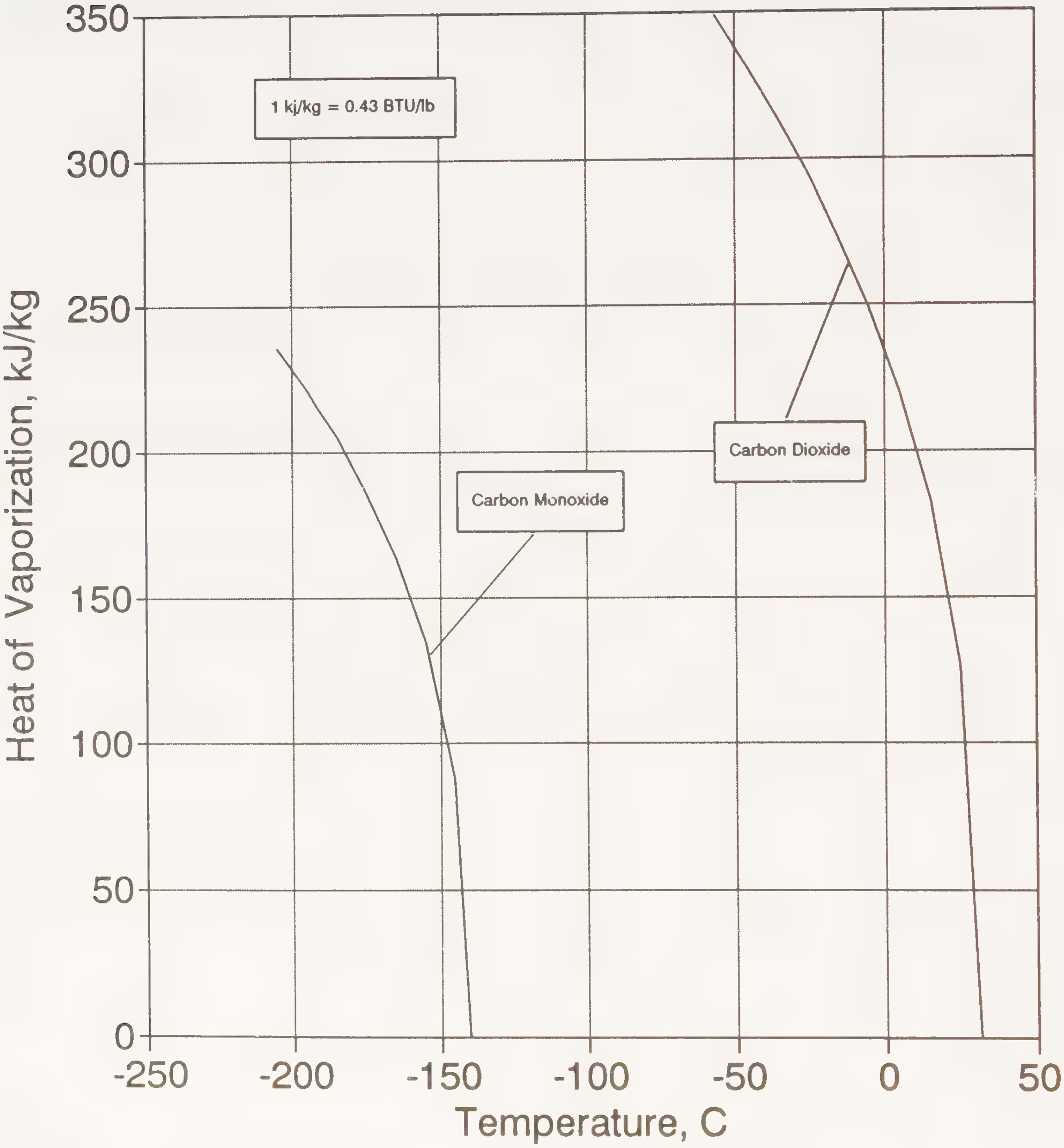

Figure 1-2 Heat of Vaporization

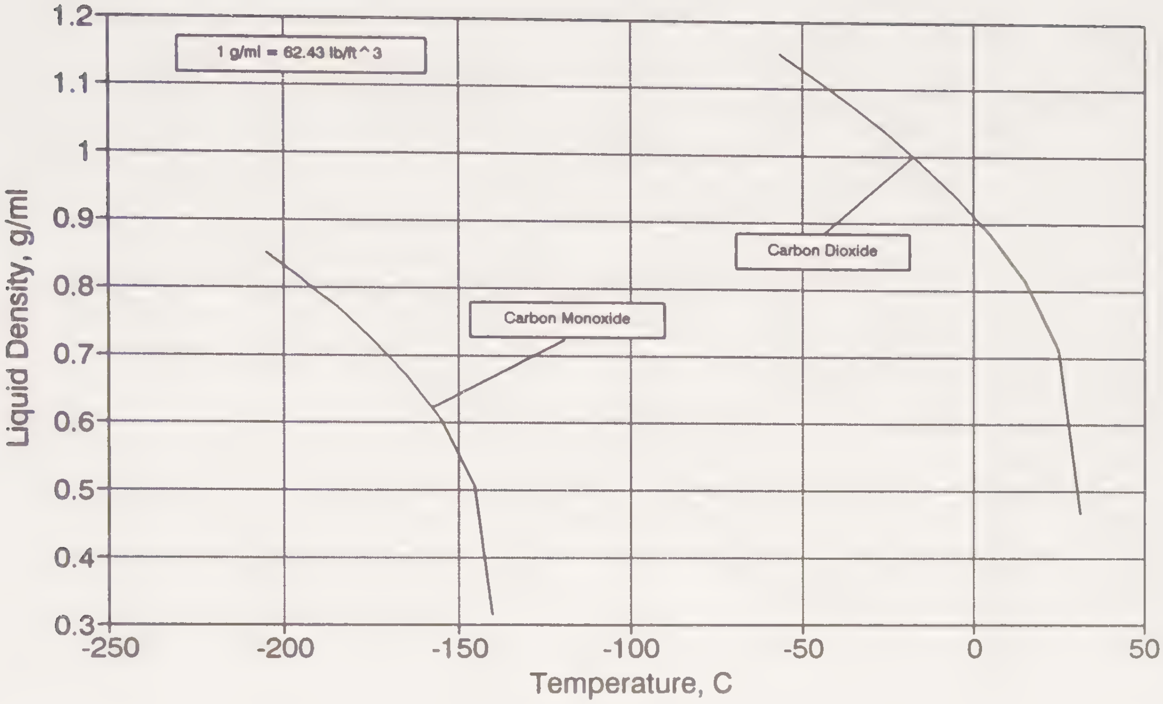

Figure 1-3 Liquid Density

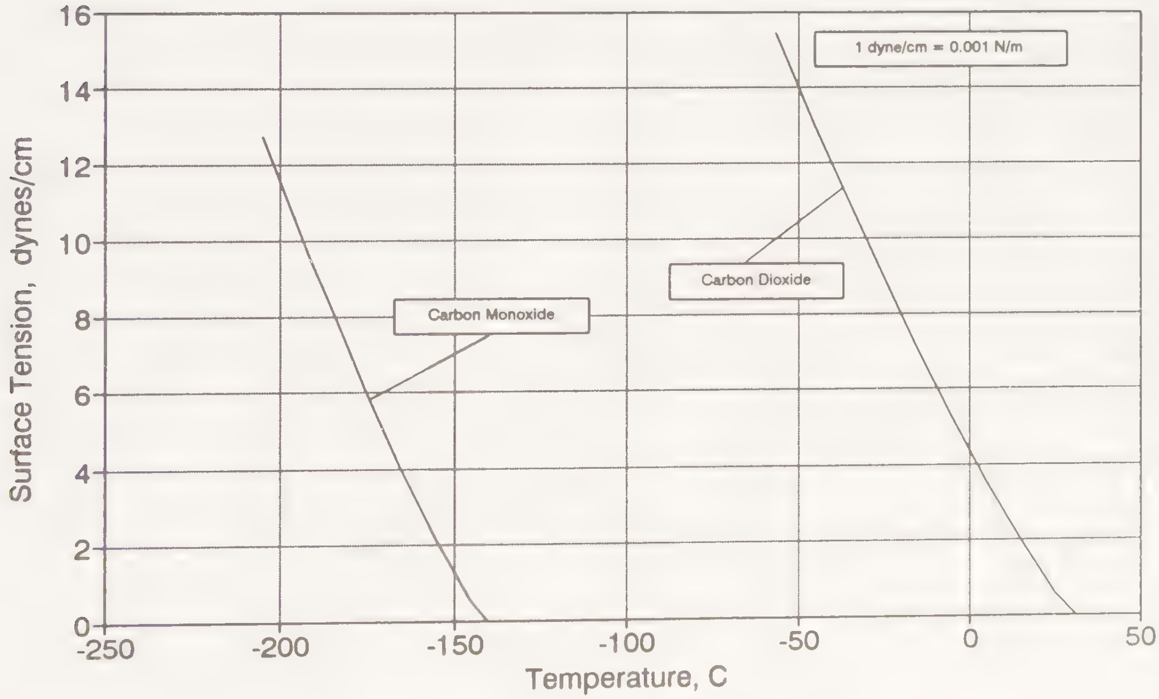

Figure 1-4 Surface Tension

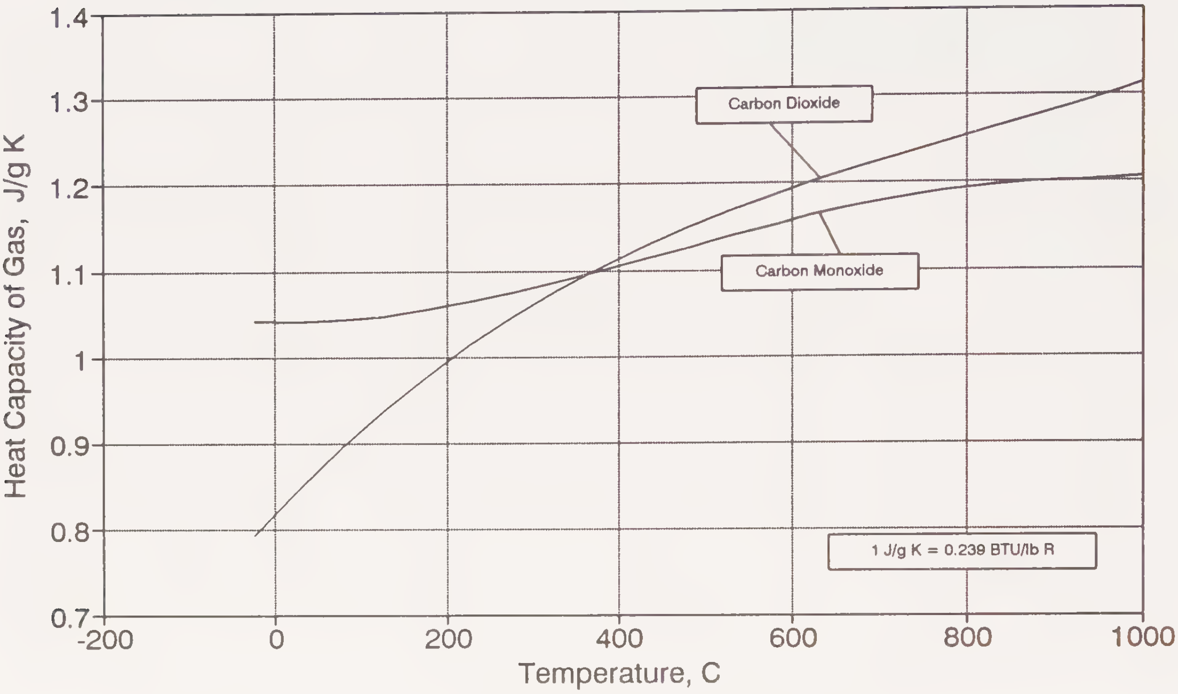

Figure 1-5 Heat Capacity of Gas

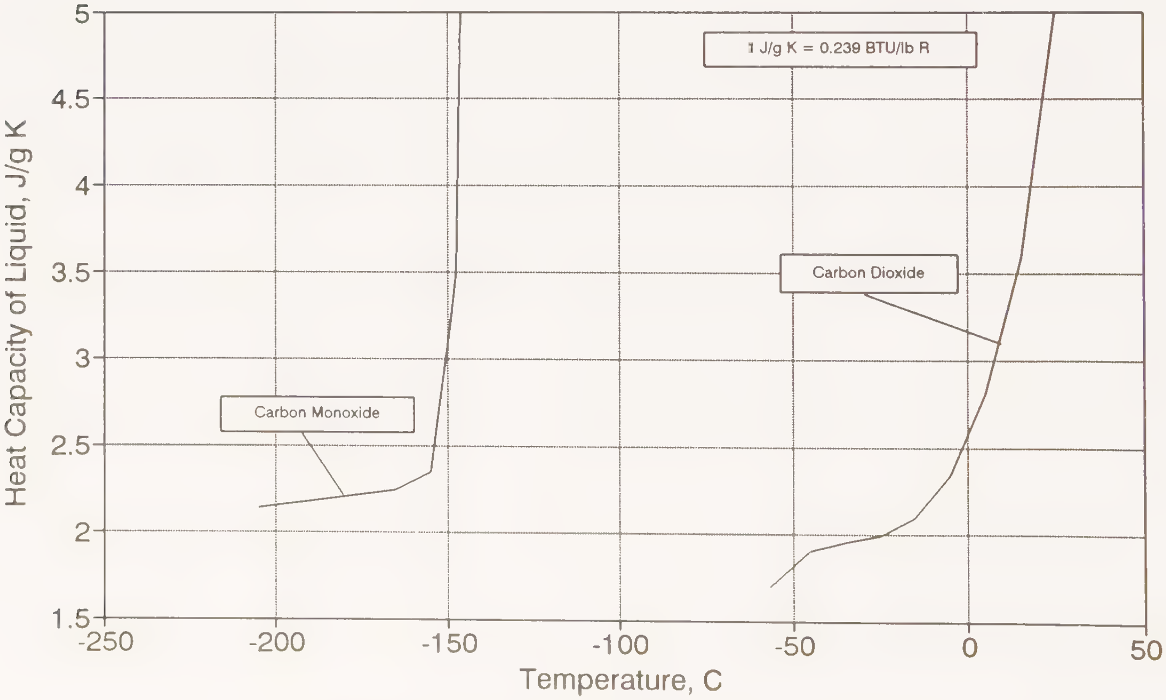

Figure 1-6 Heat Capacity of Liquid

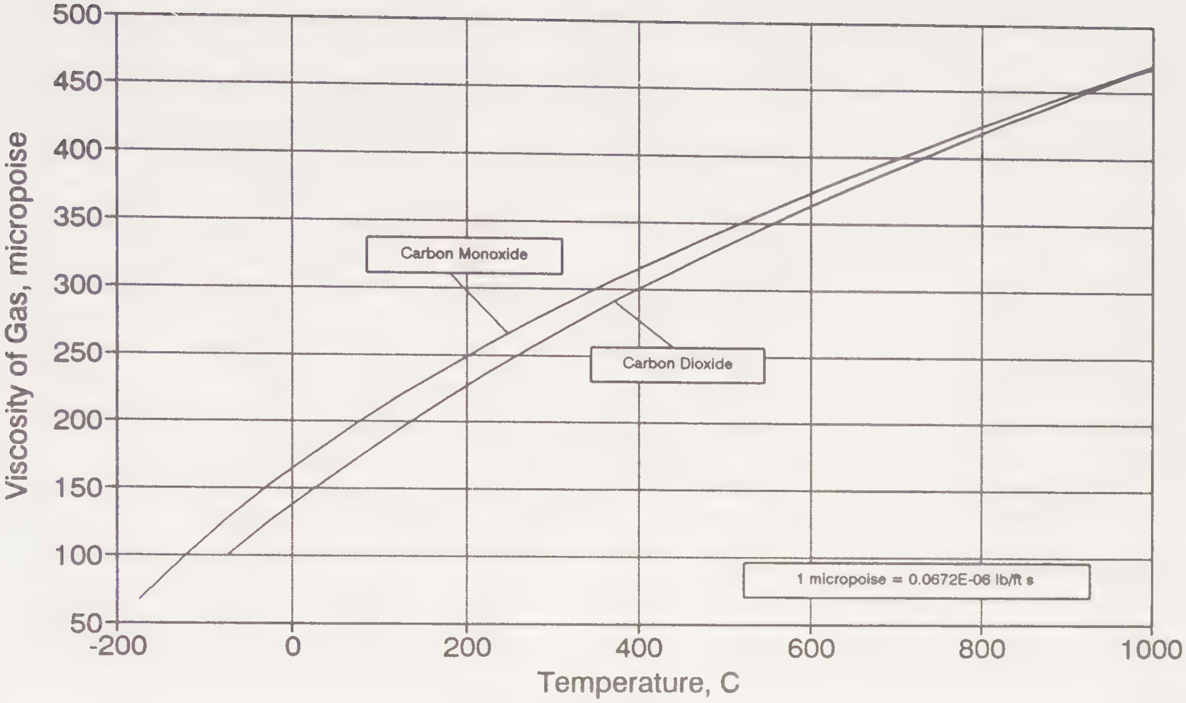

Figure 1-7 Viscosity of Gas

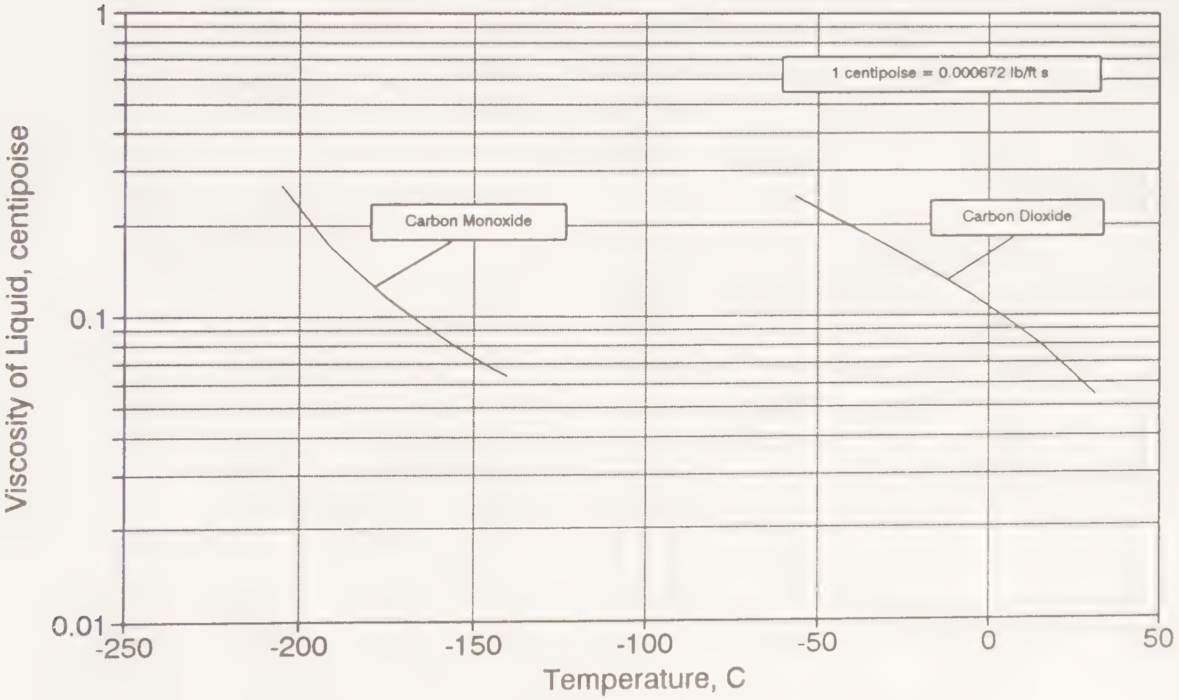

Figure 1-8 Viscosity of Liquid

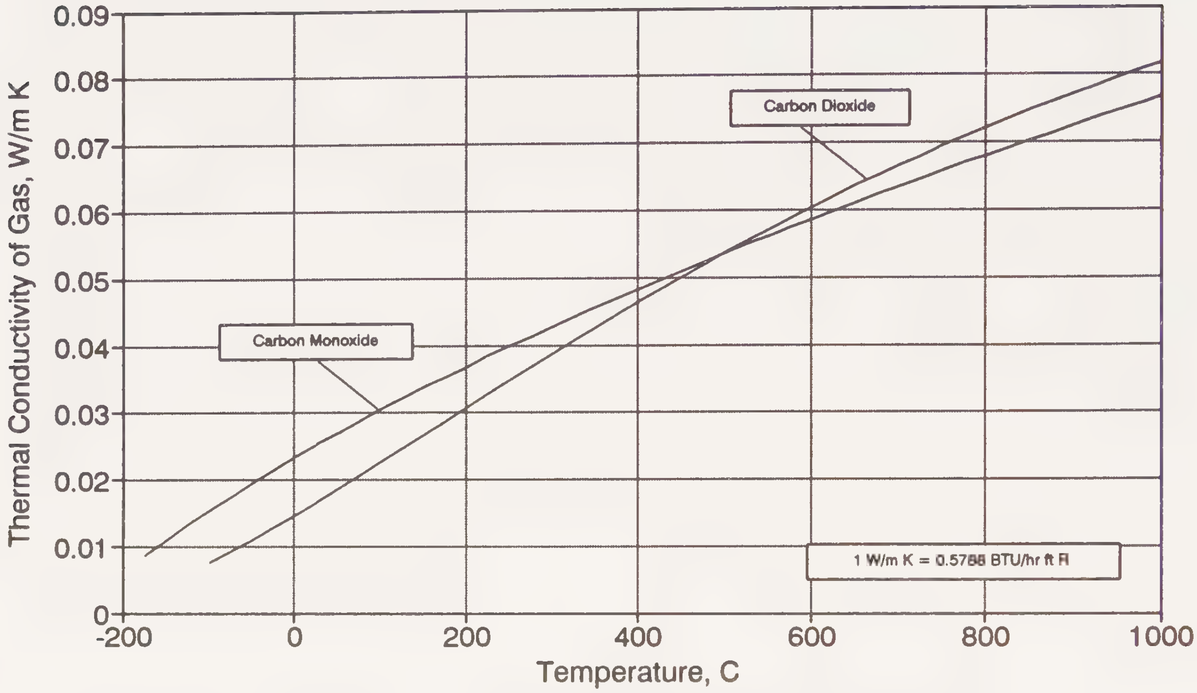

Figure 1-9 Thermal Conductivity of Gas

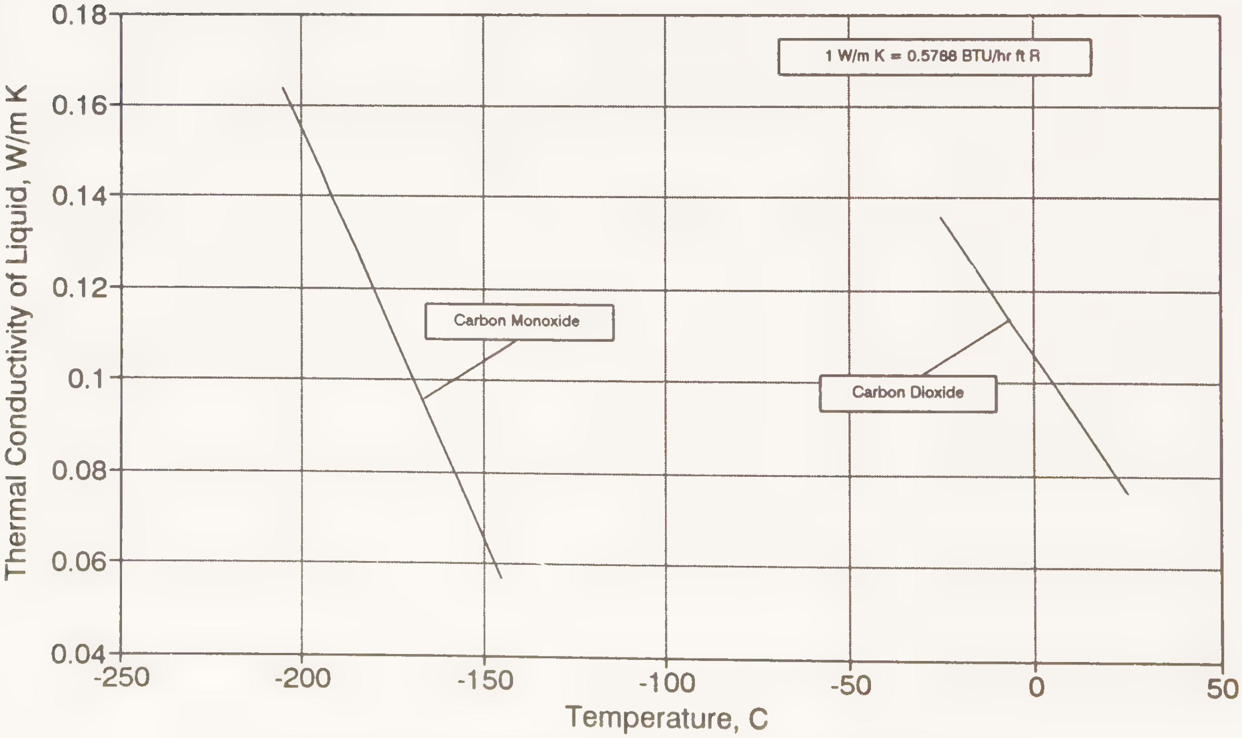

Figure 1-10 Thermal Conductivity of Liquid

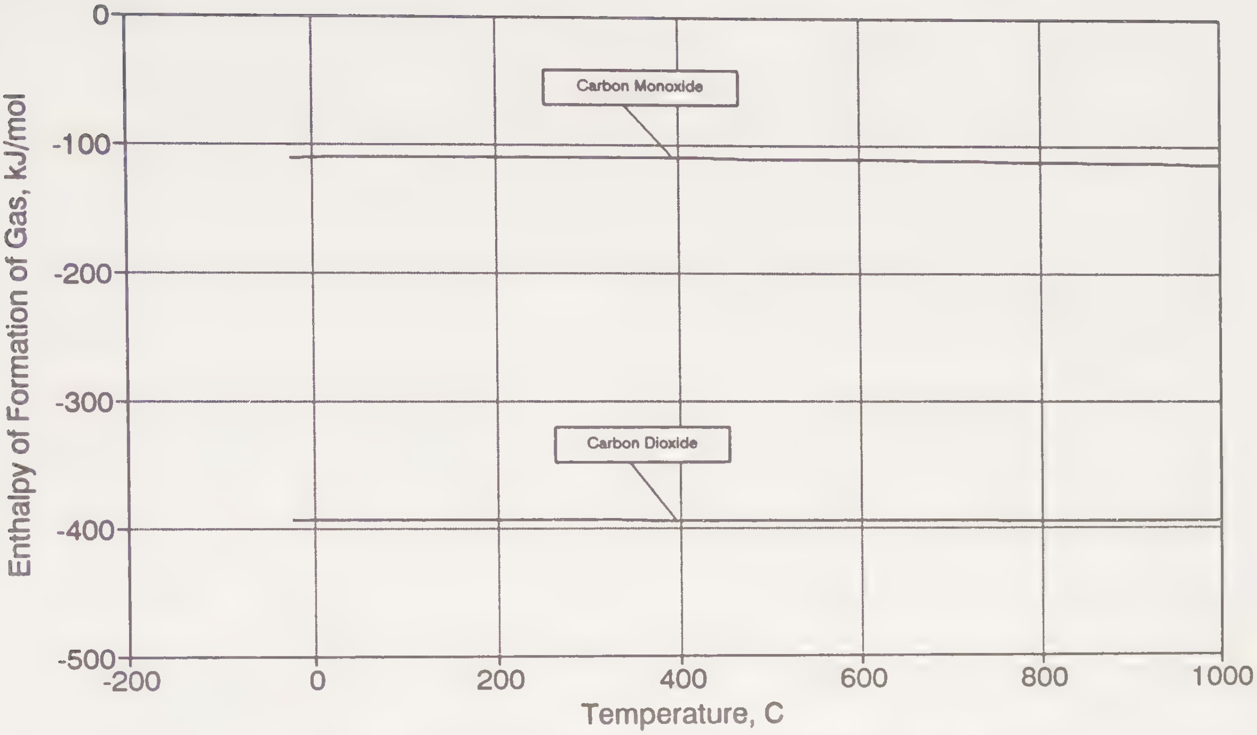

Figure 1-11 Enthalpy of Formation of Gas

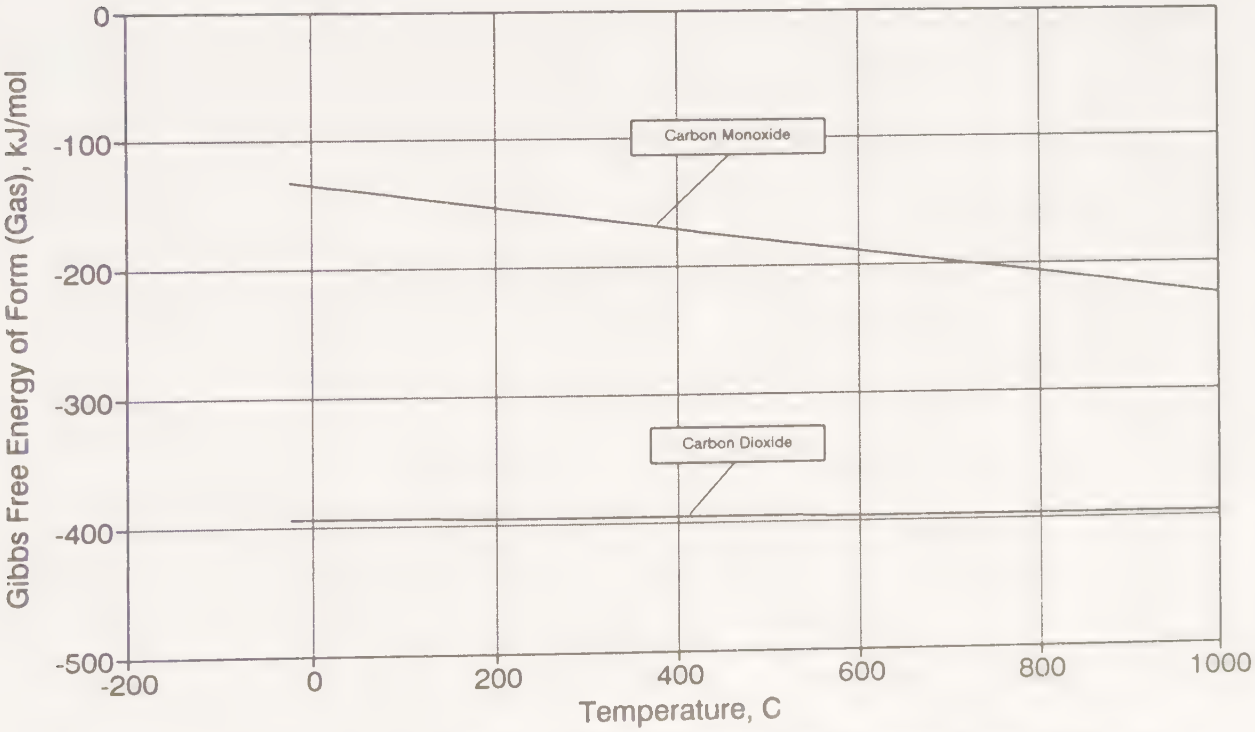

Figure 1-12 Gibbs Free Energy of Formation of Gas

Chapter 2

NITROGEN AND OXYGEN

Robert W. Gallant, Carl L. Yaws and Randy J. McDonald

PHYSICAL PROPERTIES - Table 2-1

Property data from the literature (1-28,31,36,39,42,66-71) are given in Table 2-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and data compilations by Yaws and co-workers (31) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 2-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 1% or less in most cases.

HEAT OF VAPORIZATION - Figure 2-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 2-3

Results from the data compilation of Yaws and co-workers (31) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 2% in most cases.

SURFACE TENSION - Figure 2-4

The data compilation of Yaws and co-workers (31) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 2-5 and 2-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The temperature range of coverage was extended using thermodynamic principles. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 3% or less using the correlation.

VISCOSITY - Figures 2-7 and 2-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less except for oxygen (possible 25%).

THERMAL CONDUCTIVITY - Figures 2-9 and 2-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

Table 2-1 Physical Properties

1. Name	Nitrogen	Oxygen
2. Formula	N2	O2
3. Molecular Weight, g/mol	28.013	31.999
4. Critical Temperature, K	126.10	154.58
5. Critical Pressure, bar	33.944	50.43
6. Critical Volume, ml/mol	90.10	73.40
7. Critical Compressibility Factor	0.292	0.288
8. Acentric Factor	0.0403	0.0218
9. Melting Point, K	63.15	54.36
10. Boiling Point @ 1 atm, K	77.35	90.17
11. Heat of Vaporization @ BP, kJ/kg	216.26	213.30
12. Density of Liquid @ 25 C, g/ml	------	------
13. Surface Tension @ 25 C, dynes/cm	------	------
14. Heat Capacity of Gas @ 25 C, J/g K	1.039	0.917
15. Heat Capacity of Liquid @ 25 C, J/g K	------	------
16. Viscosity of Gas @ 25 C, micropoise	177.52	204.03
17. Viscosity of Liquid @ 25 C, centipoise	------	------
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0253	0.0262
19. Thermal Conductivity of Liquid @ 25 C, W/m K	------	------
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	------	------
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	------	------
22. Flash Point, K	------	------
23. Autoignition Temperature, K	------	------
24. Lower Explosion Limit in Air, vol %	------	------
25. Upper Explosion Limit in Air, vol %	------	------
26. Solubility in Water @ 25 C, ppm(wt)	14.24 (from air)	8.11 (from air)

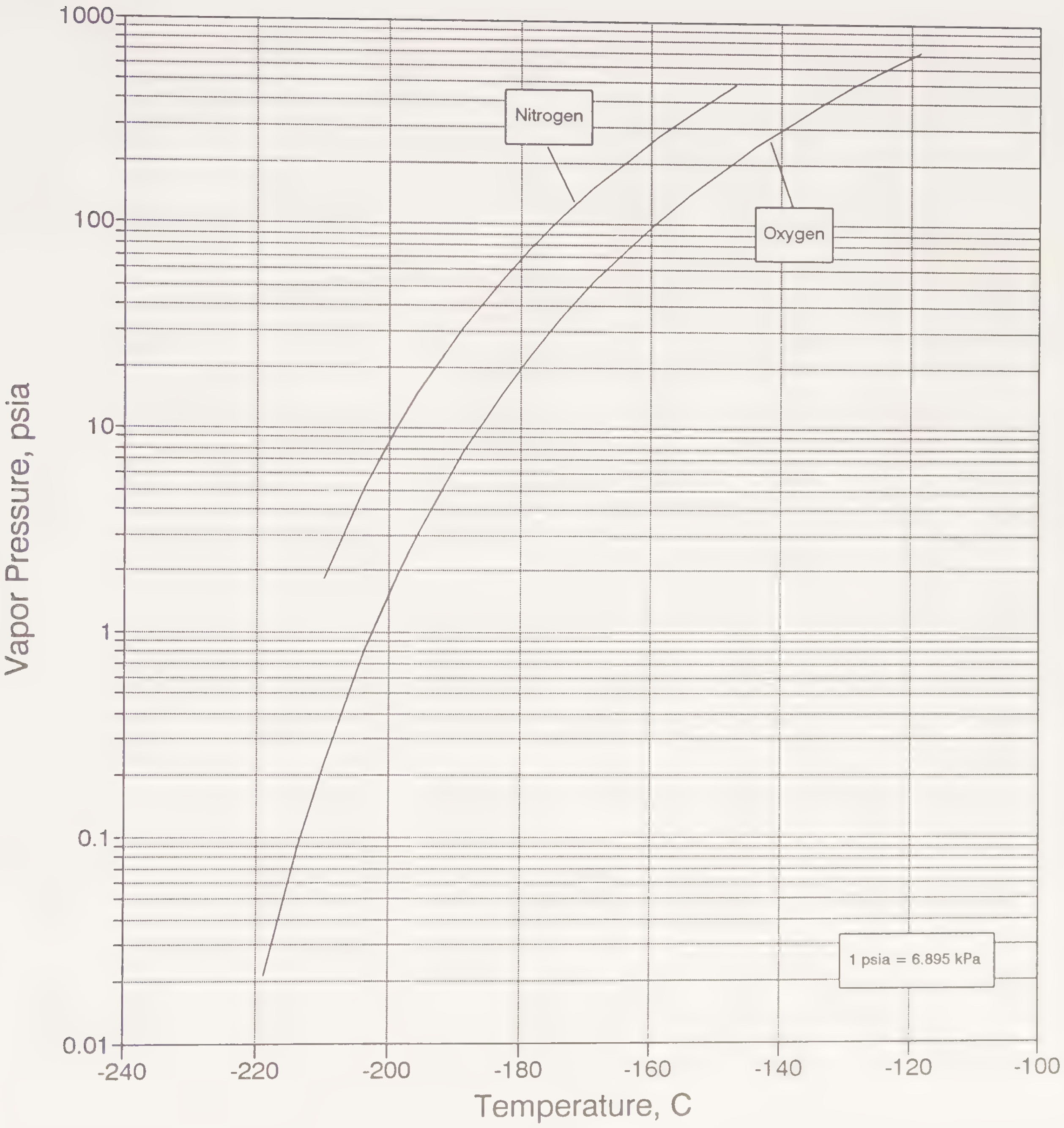

Figure 2-1 Vapor Pressure

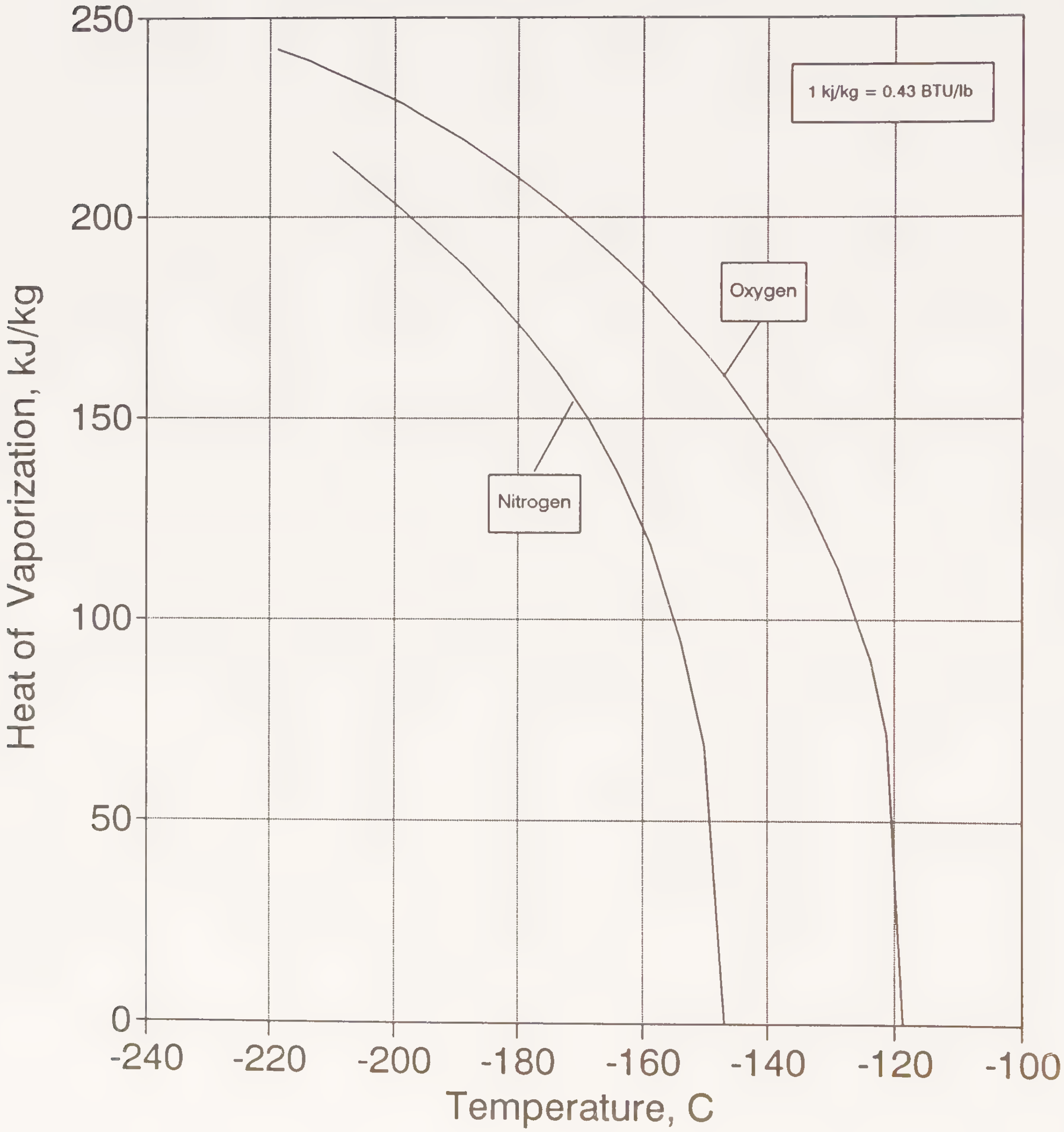

Figure 2-2 Heat of Vaporization

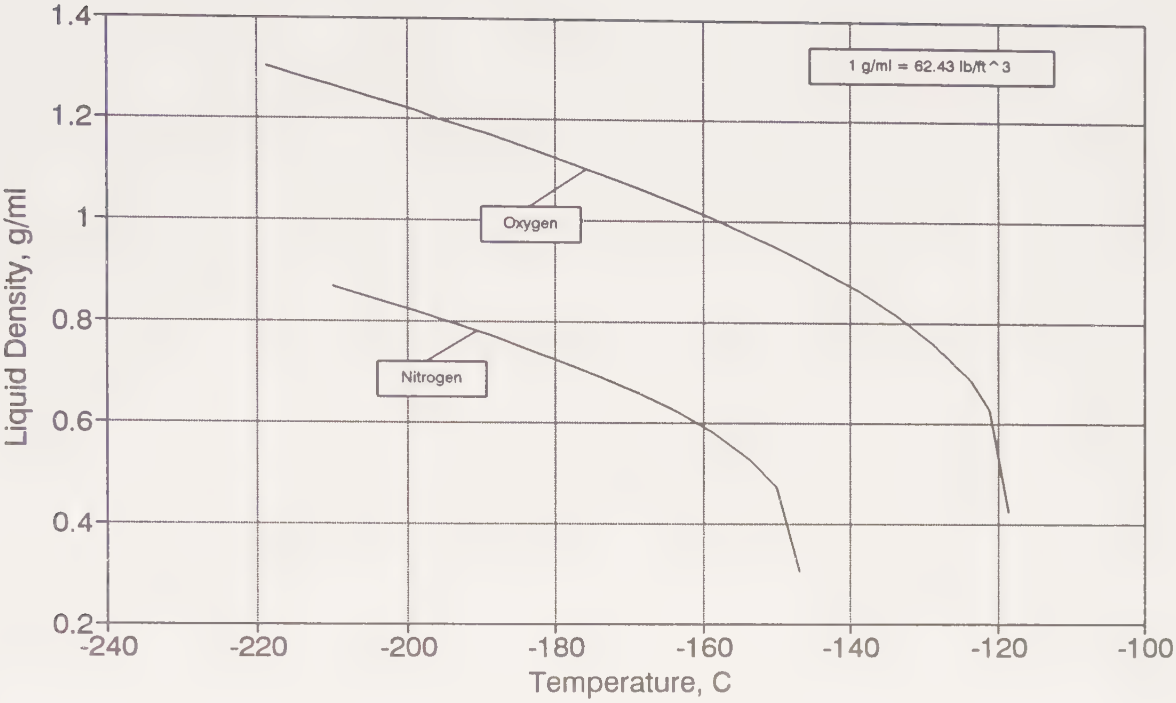

Figure 2-3 Liquid Density

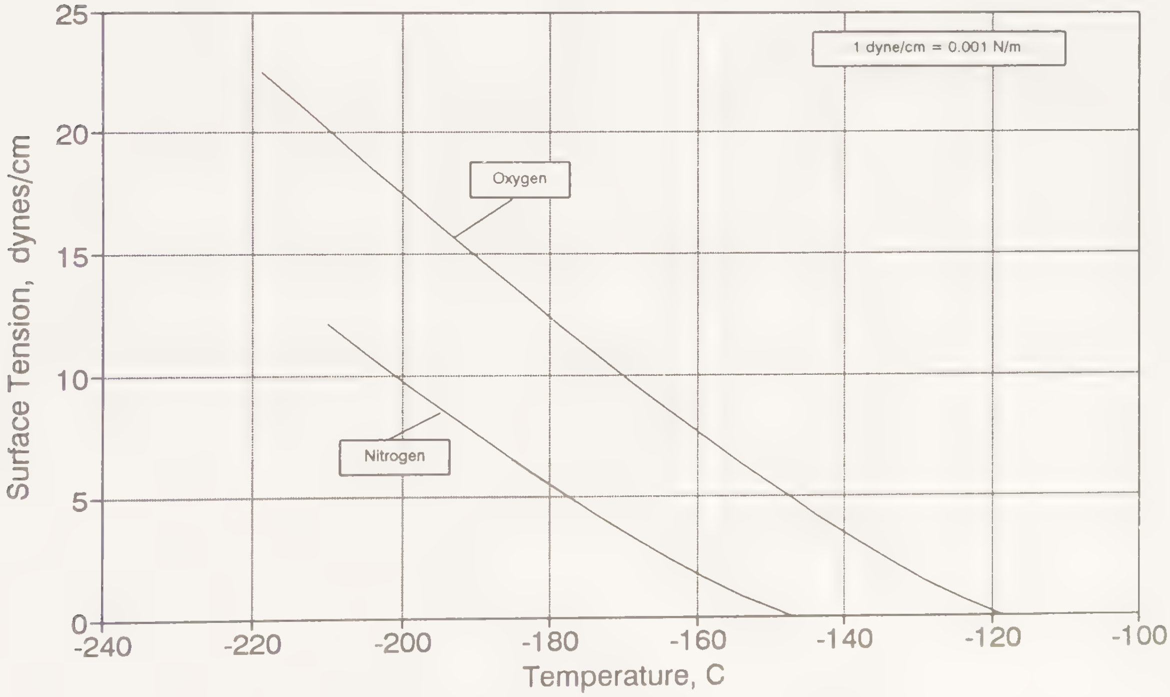

Figure 2-4 Surface Tension

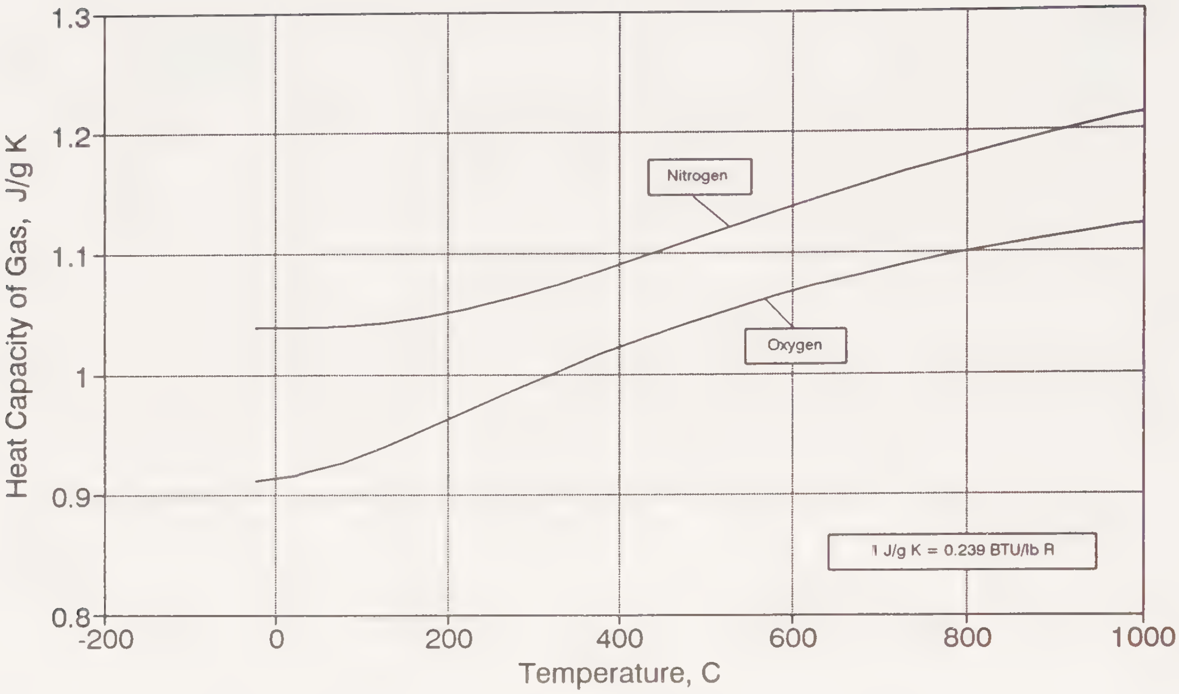

Figure 2-5 Heat Capacity of Gas

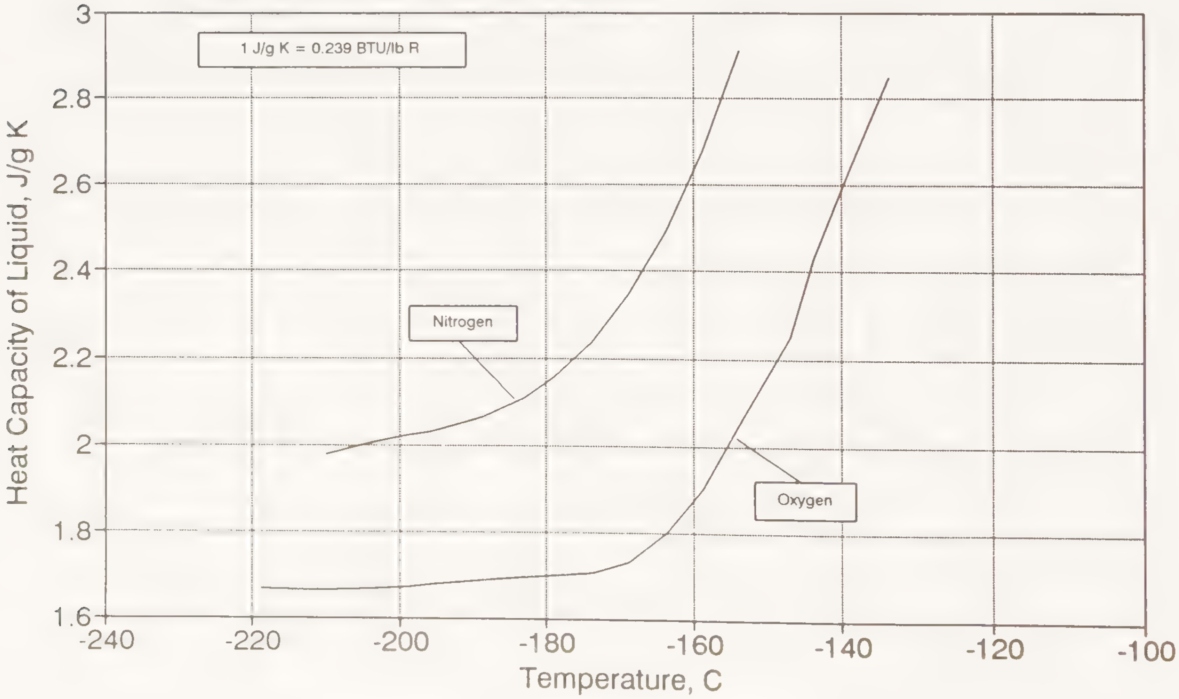

Figure 2-6 Heat Capacity of Liquid

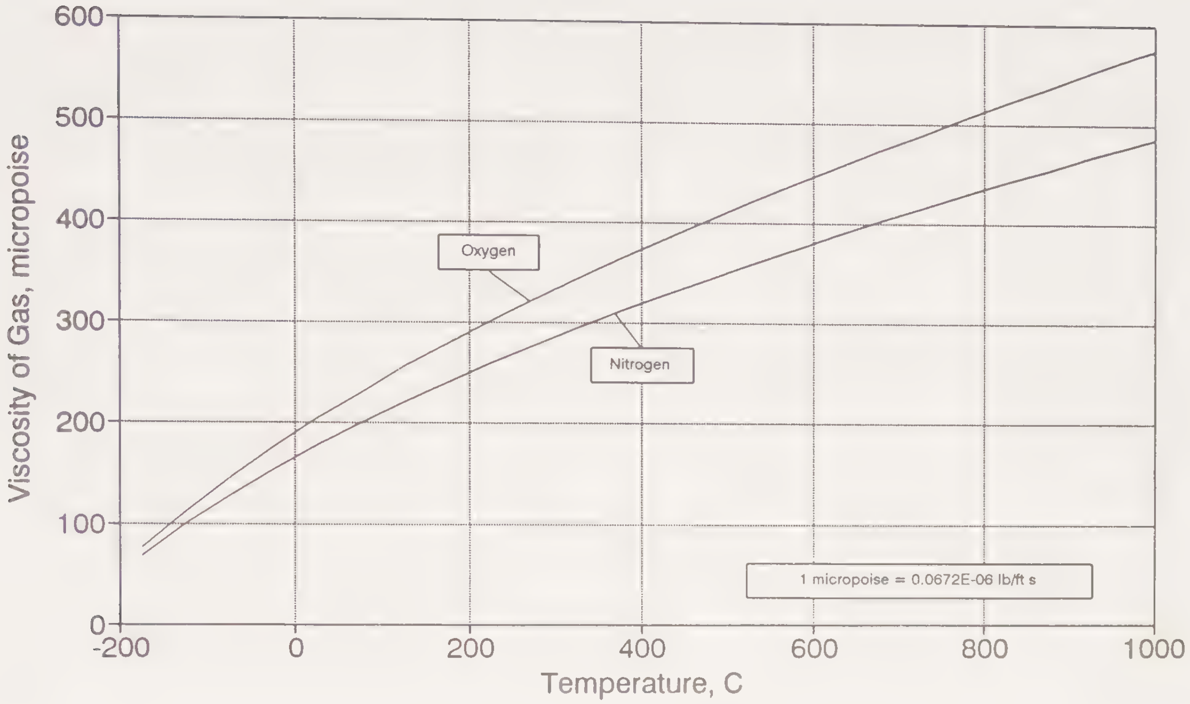

Figure 2-7 Viscosity of Gas

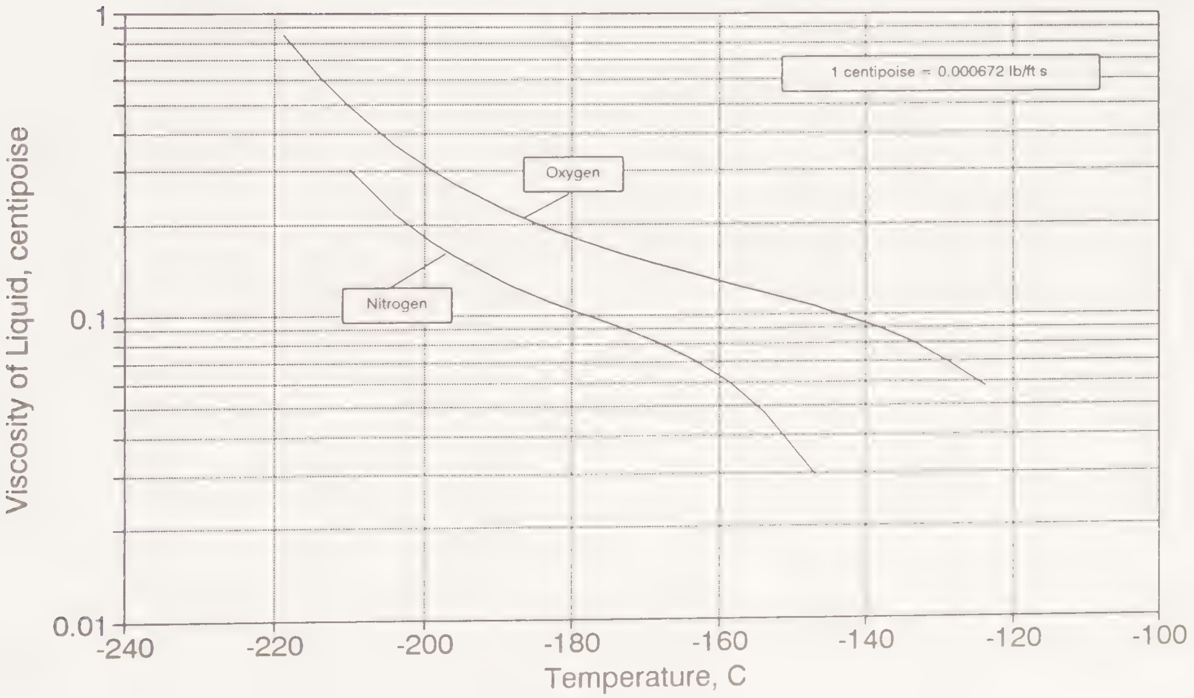

Figure 2-8 Viscosity of Liquid

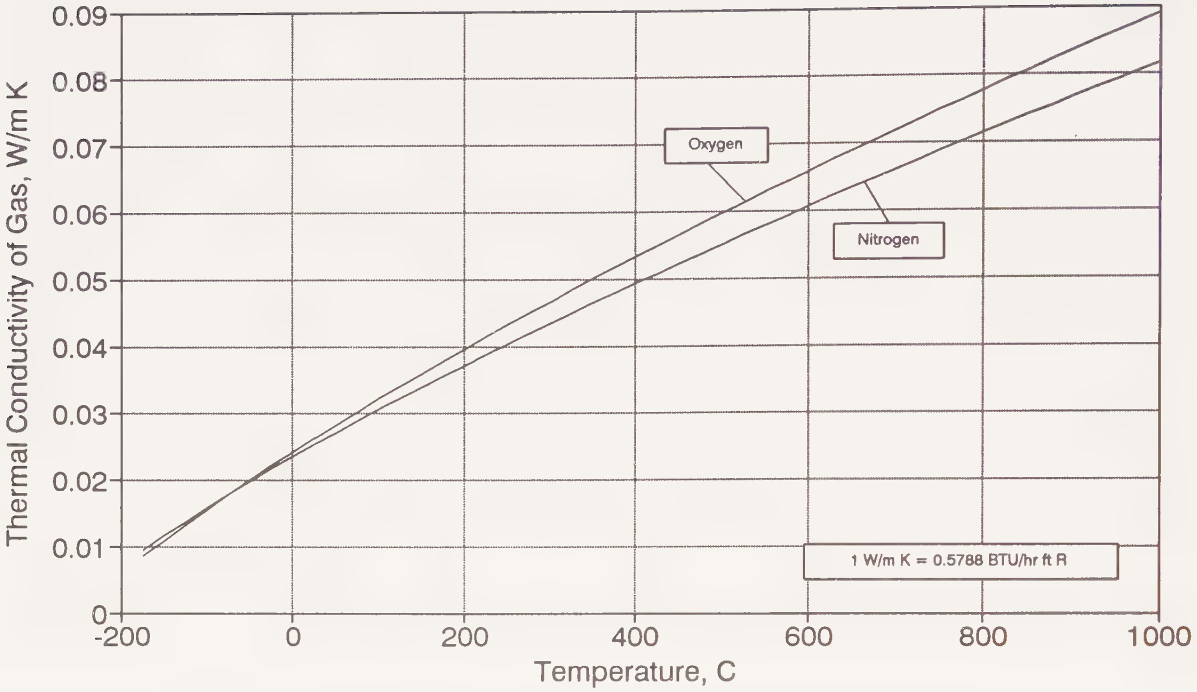

Figure 2-9 Thermal Conductivity of Gas

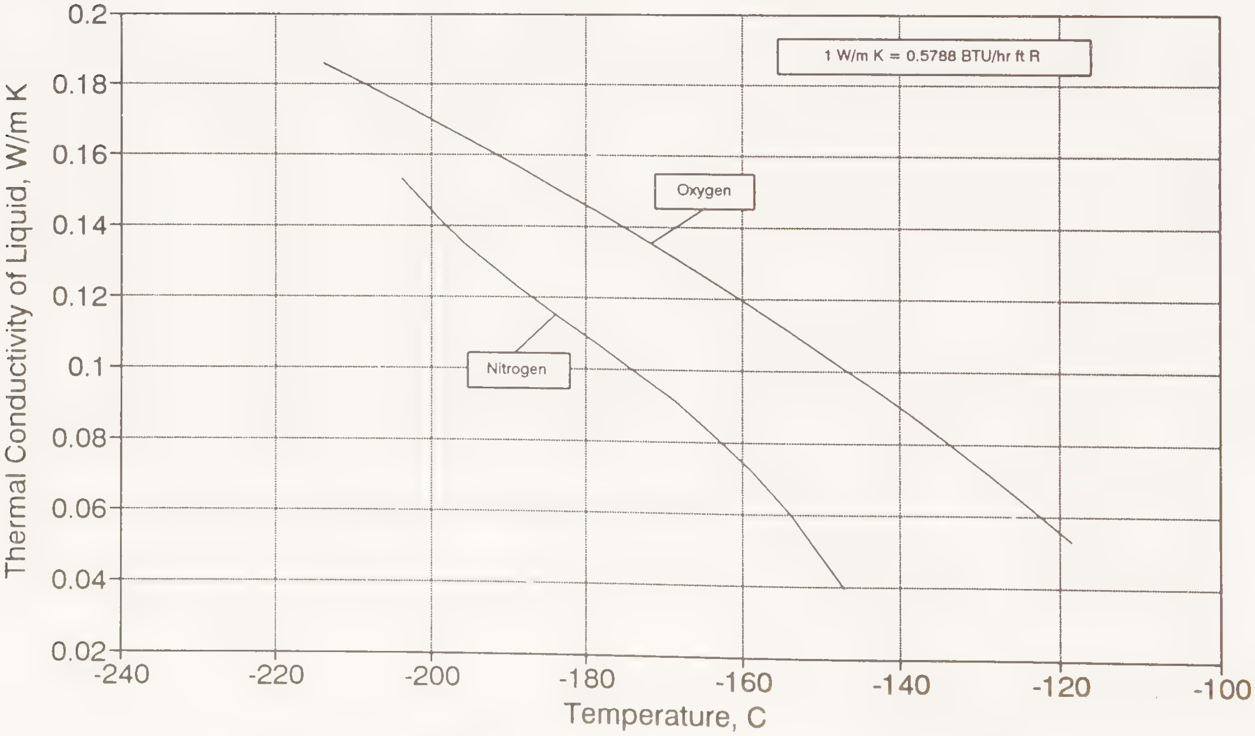

Figure 2-10 Thermal Conductivity of Liquid

Chapter 3

AIR

Robert W. Gallant, Carl L. Yaws and Jack R. Hopper

PHYSICAL PROPERTIES - Table 3-1

Property data from the literature (5,8,11,13-18,20-27,39,42,101,102) are given in Table 2-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) was consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 3-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 5% or less in most cases.

HEAT OF VAPORIZATION - Figure 3-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 3-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

HEAT CAPACITY - Figures 3-4 and 3-5

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The temperature range of coverage was extended using thermodynamic principles. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 3-6 and 3-7

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in rough agreement with errors being about 25% or less.

THERMAL CONDUCTIVITY - Figures 3-8 and 3-9

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

Table 3-1 Physical Properties

1. Name	Air
2. Formula	0.79 N2 + 0.21 O2
3. Molecular Weight, g/mol	28.850
4. Critical Temperature, K	132.45
5. Critical Pressure, bar	38.24
6. Critical Volume, ml/mol	92.17
7. Critical Compressibility Factor	0.320
8. Acentric Factor	0.0138
9. Melting Point, K	59.15
10. Boiling Point @ 1 atm, K	78.80
11. Heat of Vaporization @ BP, kJ/kg	204.94
12. Density of Liquid @ BP, g/ml	0.876
13. Surface Tension @ BP, dynes/cm	------
14. Heat Capacity of Gas @ 25 C, J/g K	1.036
15. Heat Capacity of Liquid @ BP, J/g K	1.87
16. Viscosity of Gas @ 25 C, micropoise	184.59
17. Viscosity of Liquid @ BP, centipoise	0.171
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0260
19. Thermal Conductivity of Liquid @ BP, W/m K	0.1477
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	------
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	------
22. Flash Point, K	------
23. Autoignition Temperature, K	------
24. Lower Explosion Limit in Air, vol %	------
25. Upper Explosion Limit in Air, vol %	------
26. Solubility in Water @ 25 C, ppm(wt)	------

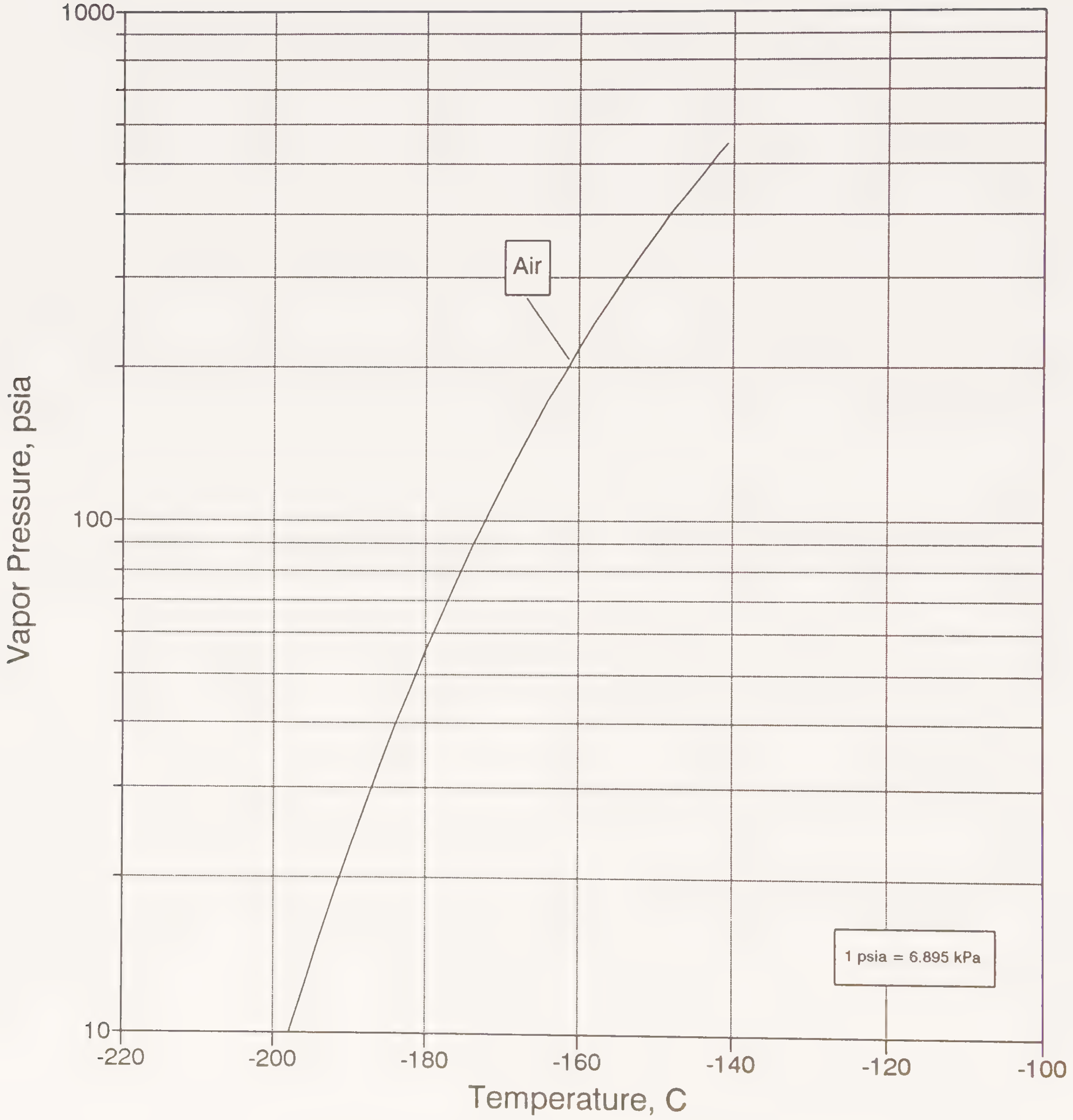

Figure 3-1 Vapor Pressure

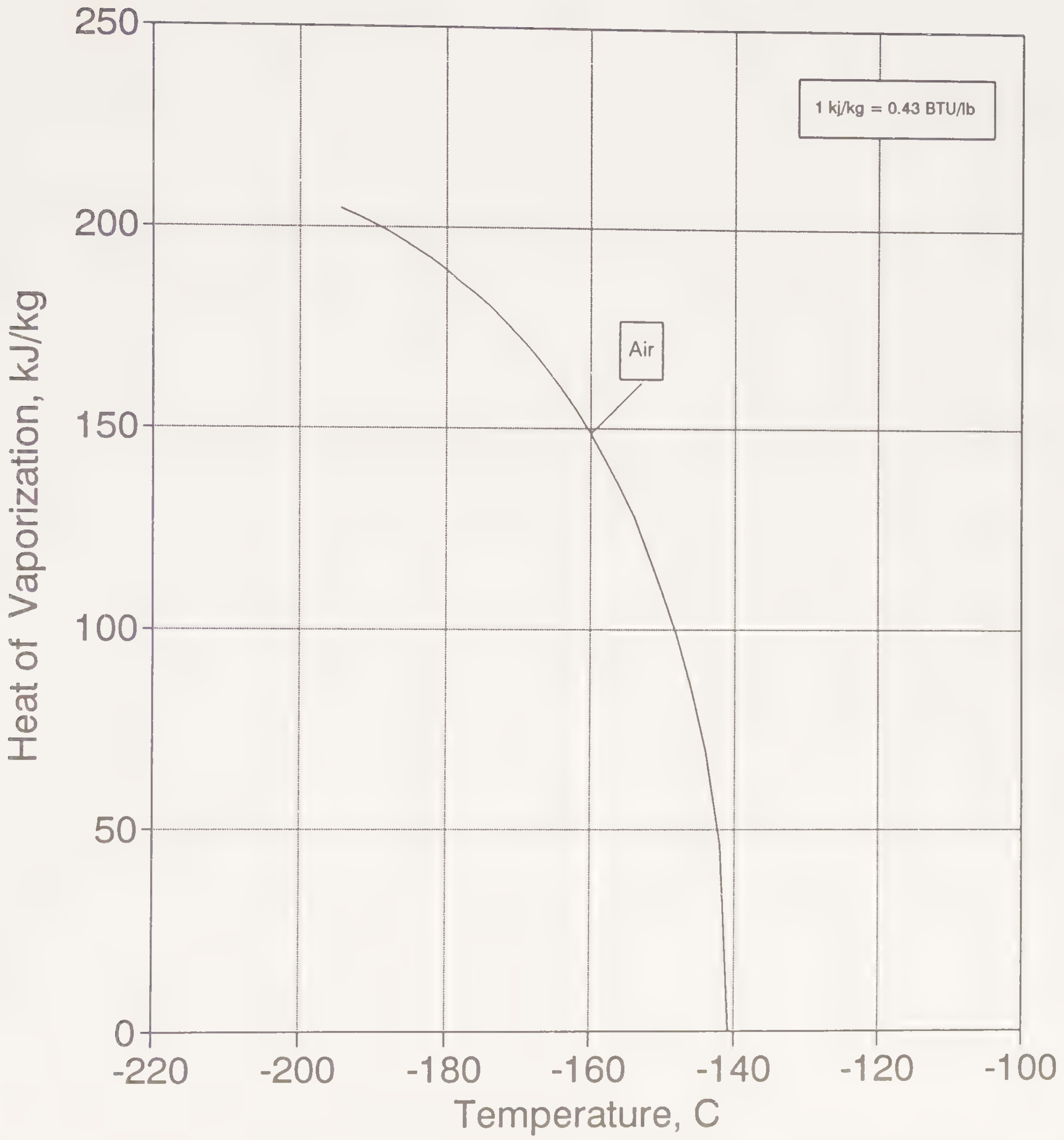

Figure 3-2 Heat of Vaporization

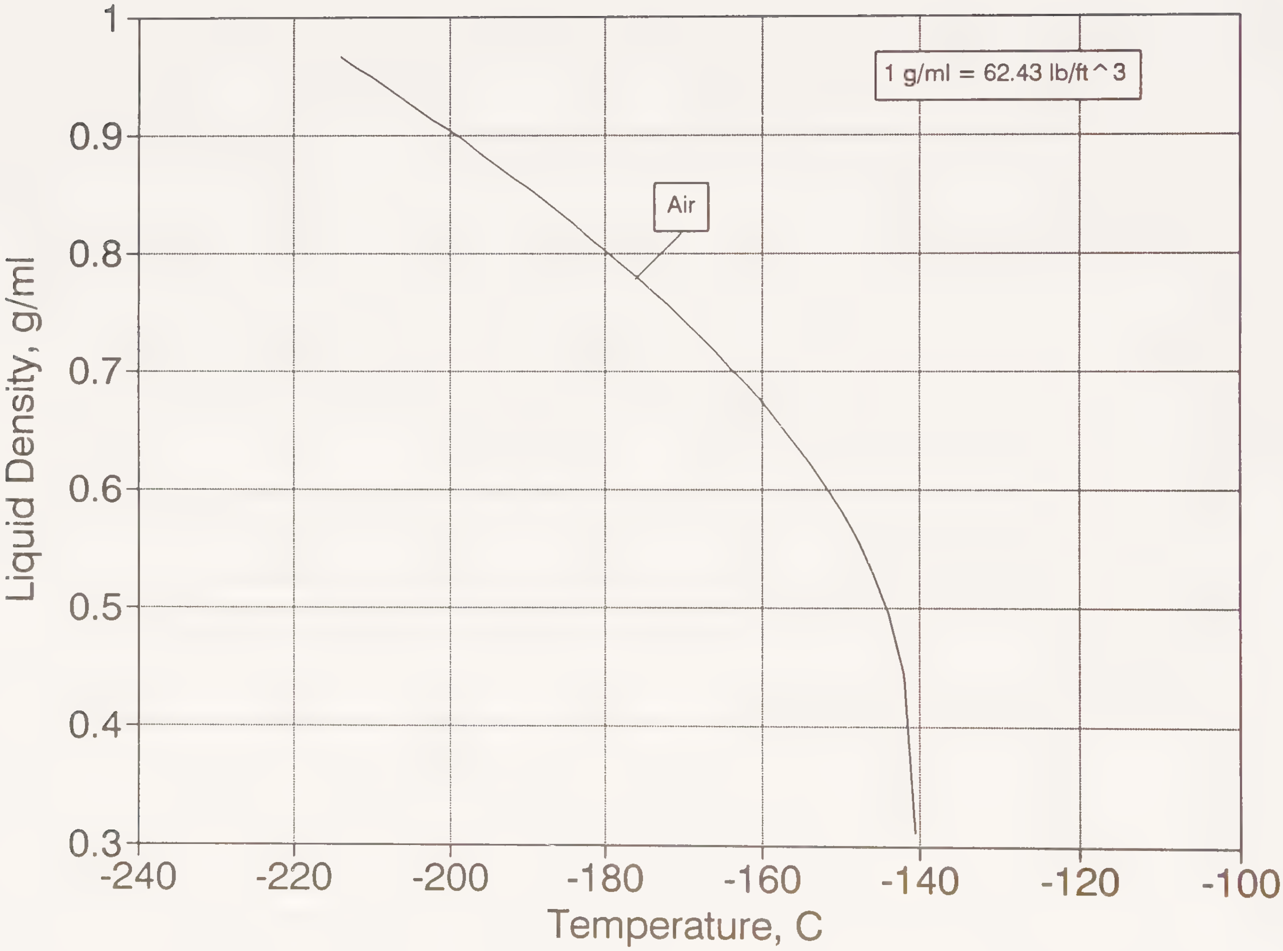

Figure 3-3 Liquid Density

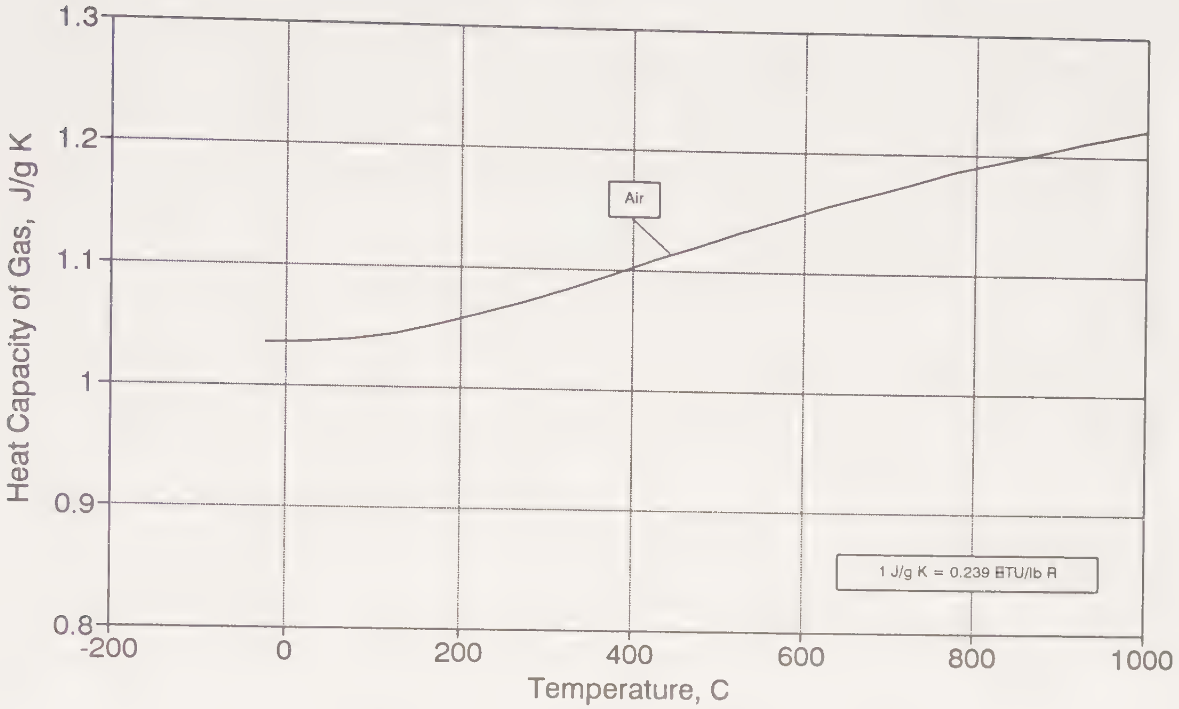

Figure 3-4 Heat Capacity of Gas

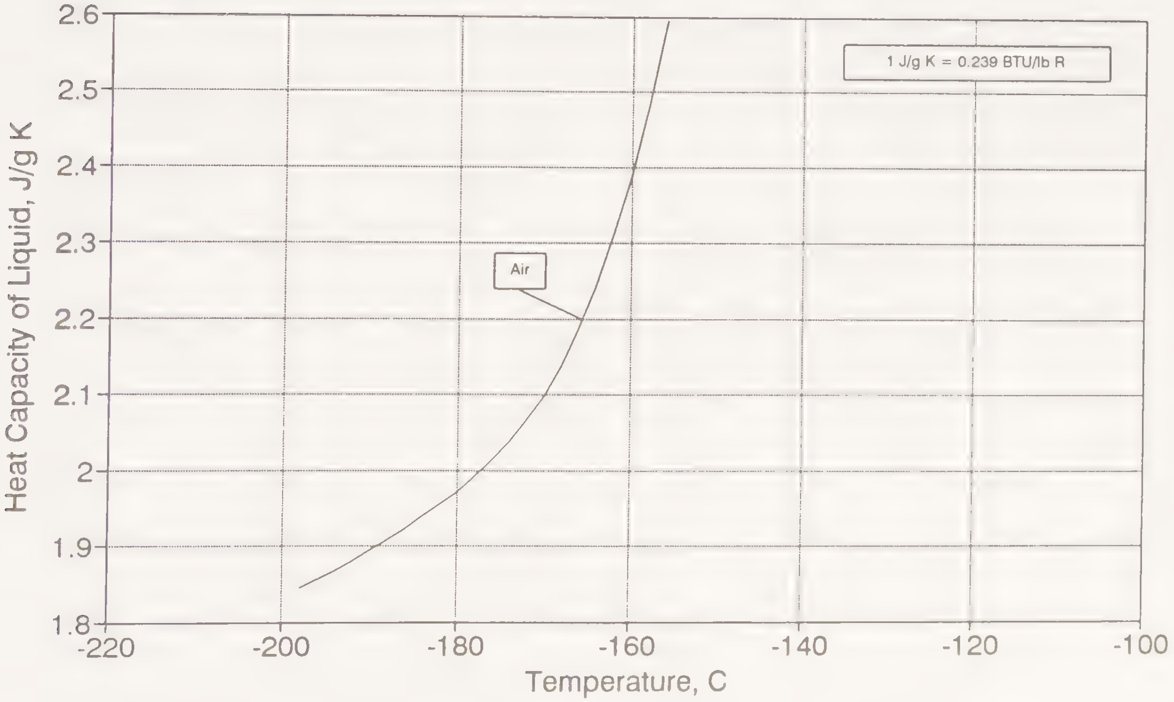

Figure 3-5 Heat Capacity of Liquid

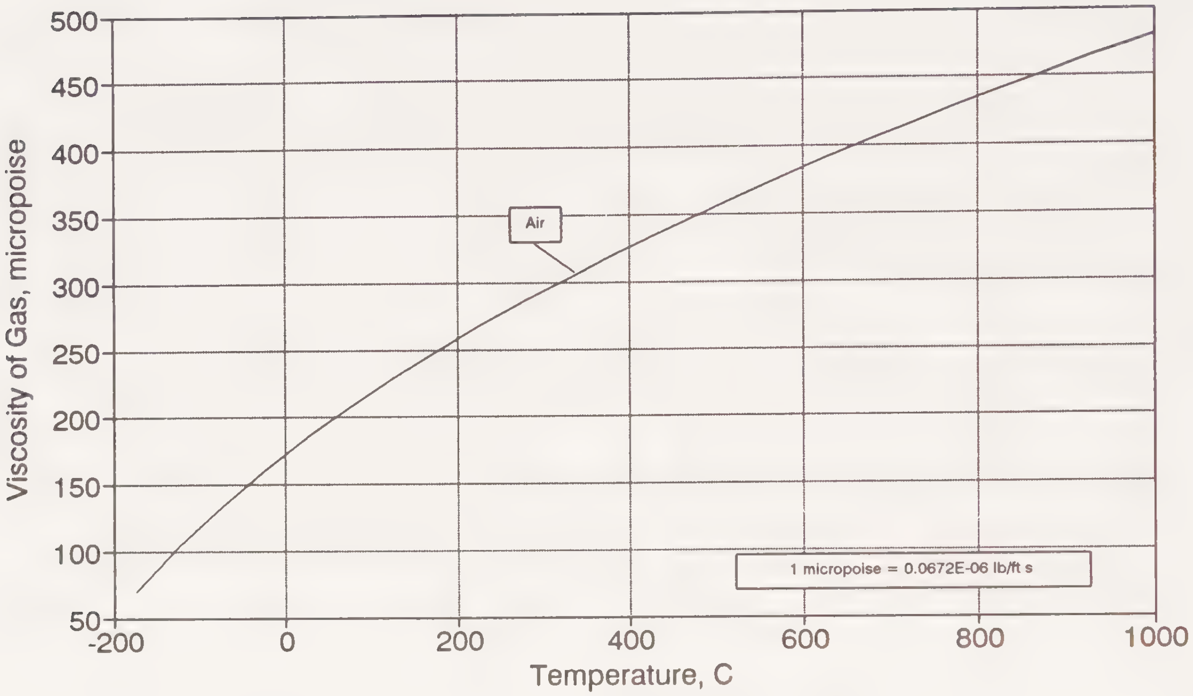

Figure 3-6 Viscosity of Gas

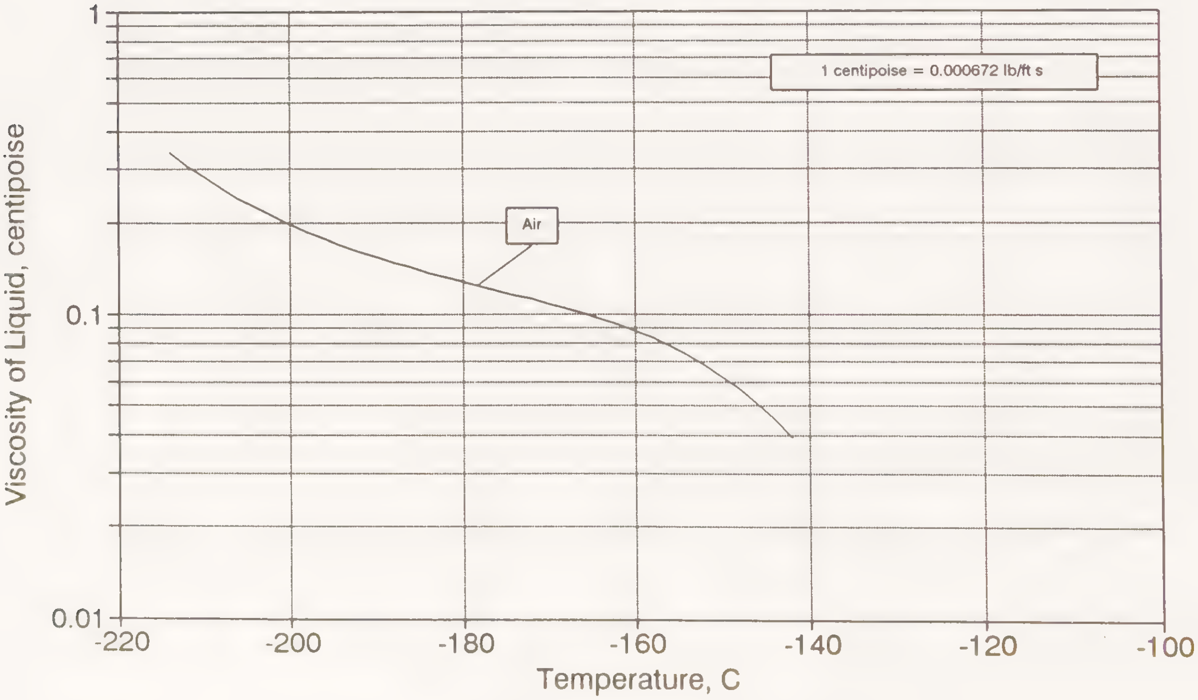

Figure 3-7 Viscosity of Liquid

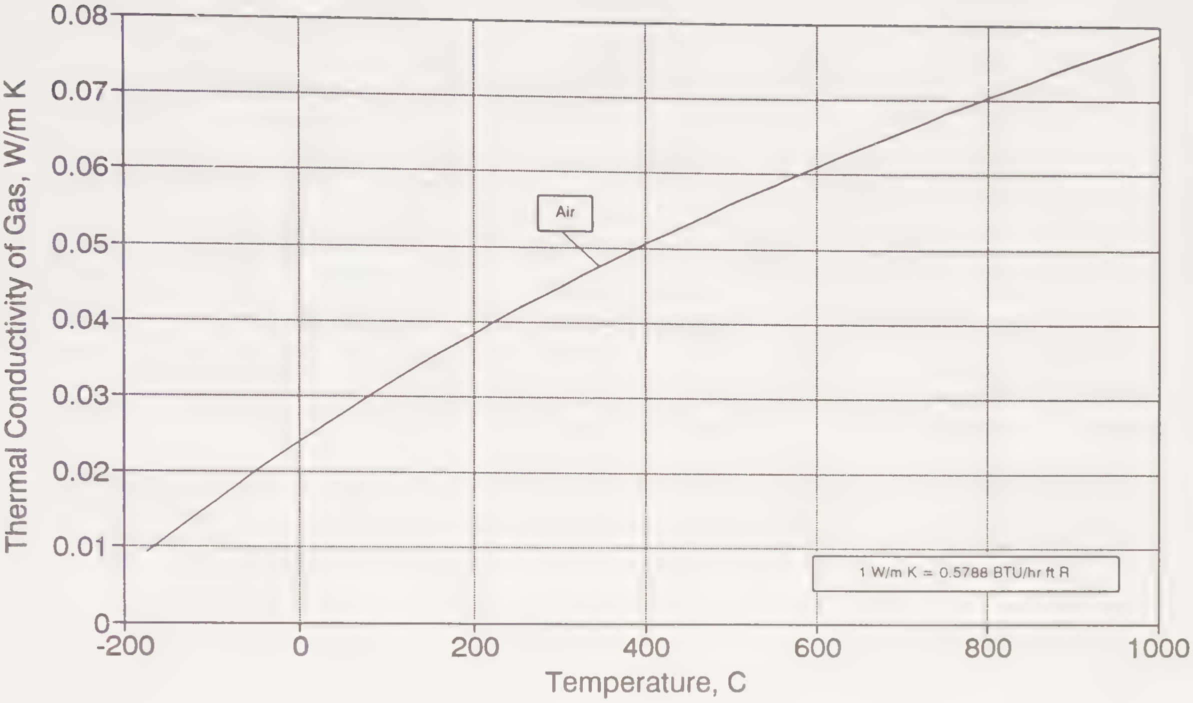

Figure 3-8 Thermal Conductivity of Gas

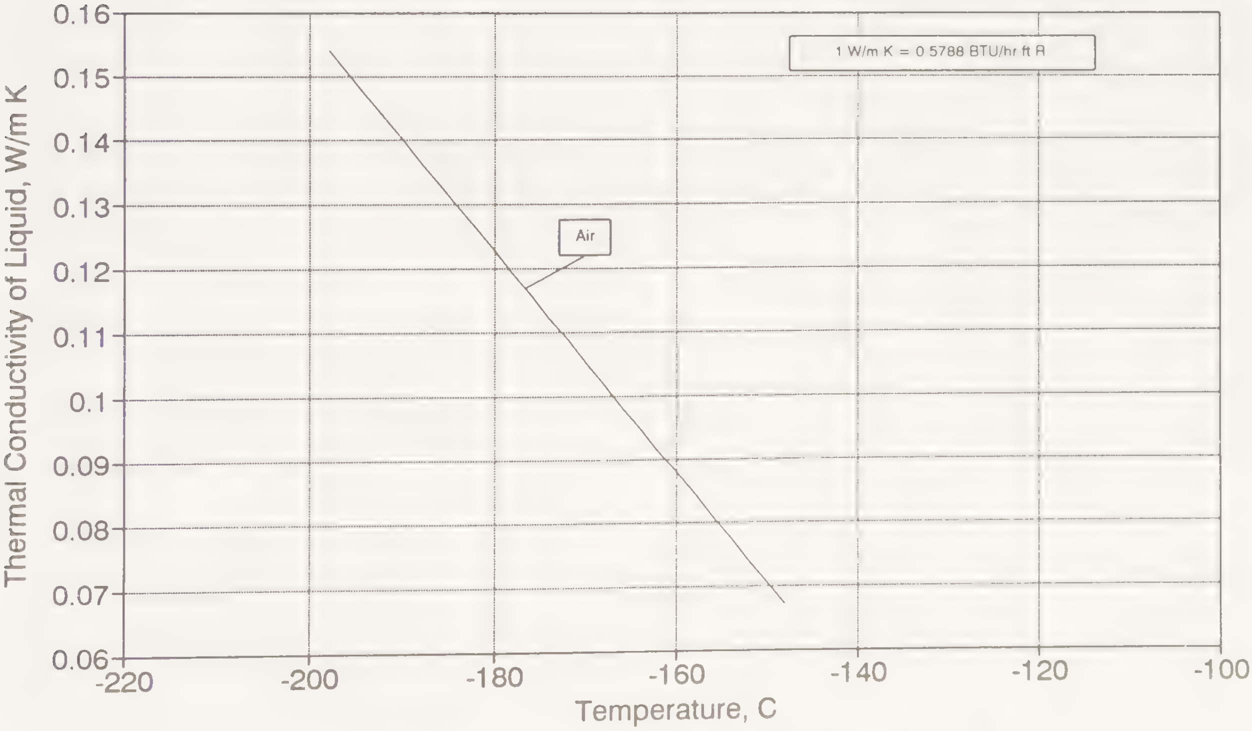

Figure 3-9 Thermal Conductivity of Liquid

Chapter 4

OZONE

Robert W. Gallant, Carl L. Yaws and Jack R. Hopper

PHYSICAL PROPERTIES - Table 4-1

Property data from the literature (2,3,5-8,13-17,26,27,36,37,102-107) are given in Table 4-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) was consulted extensively in preparing the tabulation.

Ozone is a very strong oxidizing agent. Precautions should be taken to prevent combustible materials such as oil, grease and similar substances. Ozone is a severe explosion hazard in liquid form when exposed to heat or flame.

VAPOR PRESSURE - Figure 4-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 5% or less in most cases.

HEAT OF VAPORIZATION - Figure 4-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 4-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 4-4

Results from the DIPPR project (5) were selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 4-5 and 4-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The temperature range of coverage was extended using thermodynamic principles. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 3% or less using the correlation.

VISCOSITY - Figures 4-7 and 4-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in agreement with data. Errors are about 10% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 4-9 and 4-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is rough with errors of about 25% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

ENTHALPY OF FORMATION - Figure 4-11

Results from the DIPPR project (5) and JANAF tables (37) were selected for enthalpy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 4-12

Results from the DIPPR project (5) and JANAF tables (37) were selected for Gibb's free energy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-12). Results from the correlation are in favorable agreement with data.

Table 4-1 Physical Properties

1. Name	Ozone
2. Formula	O3
3. Molecular Weight, g/mol	47.998
4. Critical Temperature, K	261.00
5. Critical Pressure, bar	55.729
6. Critical Volume, ml/mol	89.00
7. Critical Compressibility Factor	0.229
8. Acentric Factor	0.1947
9. Melting Point, K	80.15
10. Boiling Point @ 1 atm, K	161.85
11. Heat of Vaporization @ BP, kJ/kg	294.50
12. Density of Liquid @ BP, g/ml	1.348
13. Surface Tension @ BP, dynes/cm	13.93
14. Heat Capacity of Gas @ 25 C, J/g K	0.817
15. Heat Capacity of Liquid @ BP, J/g K	-----
16. Viscosity of Gas @ 25 C, micropoise	133.06
17. Viscosity of Liquid @ BP, centipoise	0.271
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0141
19. Thermal Conductivity of Liquid @ BP, W/m K	------
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	142.71
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	163.22
22. Flash Point, K	------
23. Autoignition Temperature, K	------
24. Lower Explosion Limit in Air, vol %	------
25. Upper Explosion Limit in Air, vol %	------
26. Solubility in Water @ 0 C, ppm(wt)	1,059

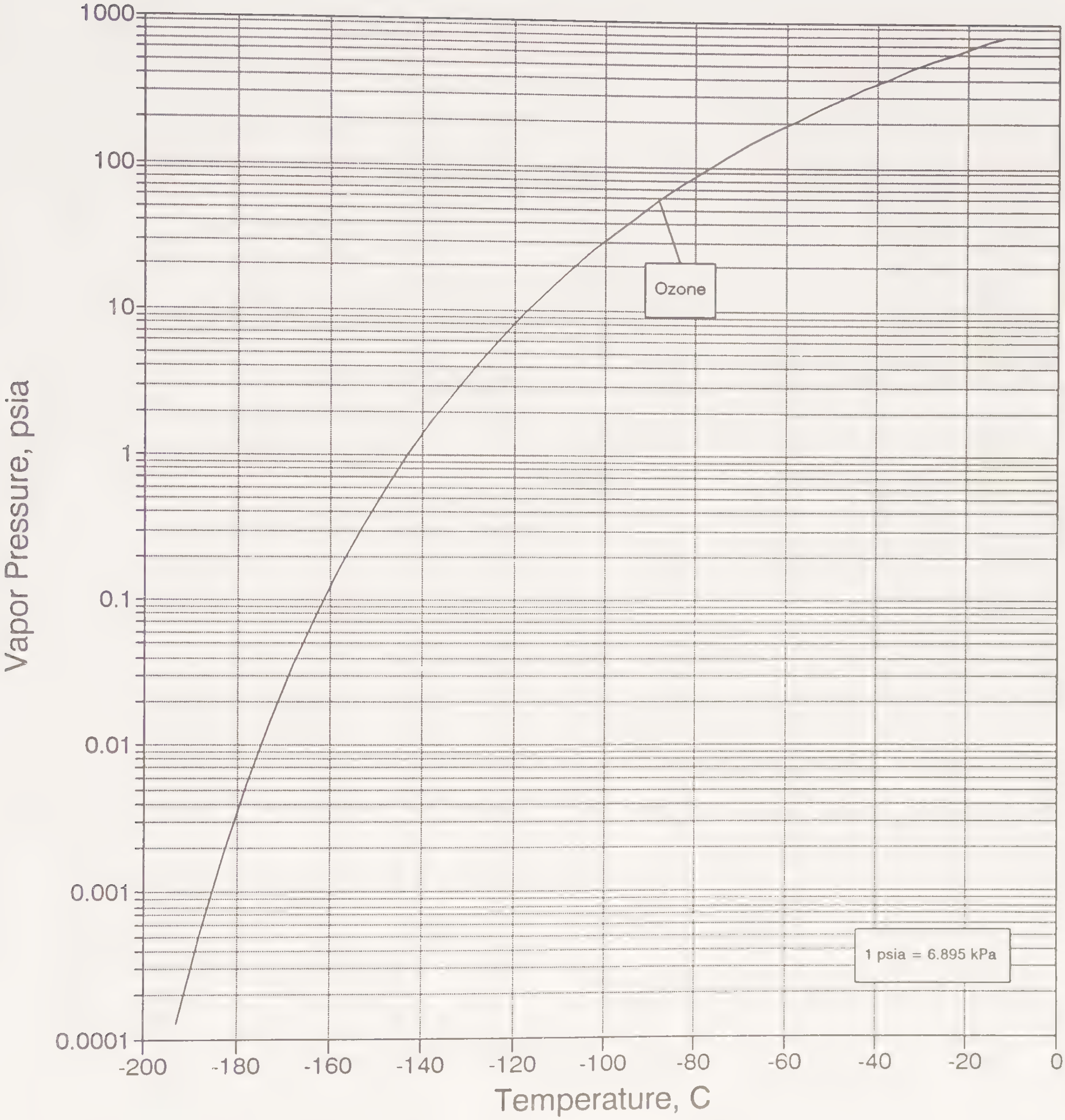

Figure 4-1 Vapor Pressure

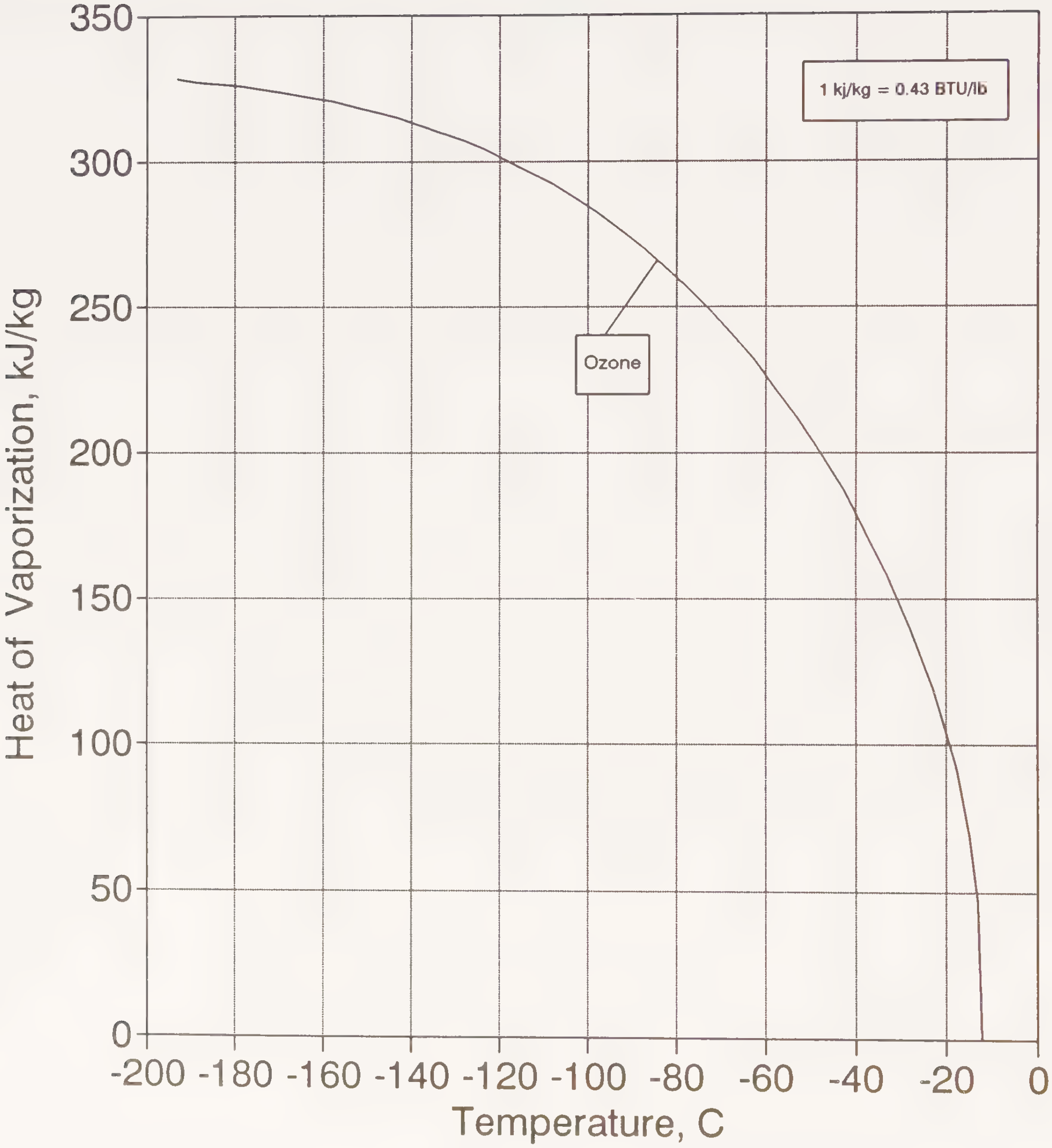

Figure 4-2 Heat of Vaporization

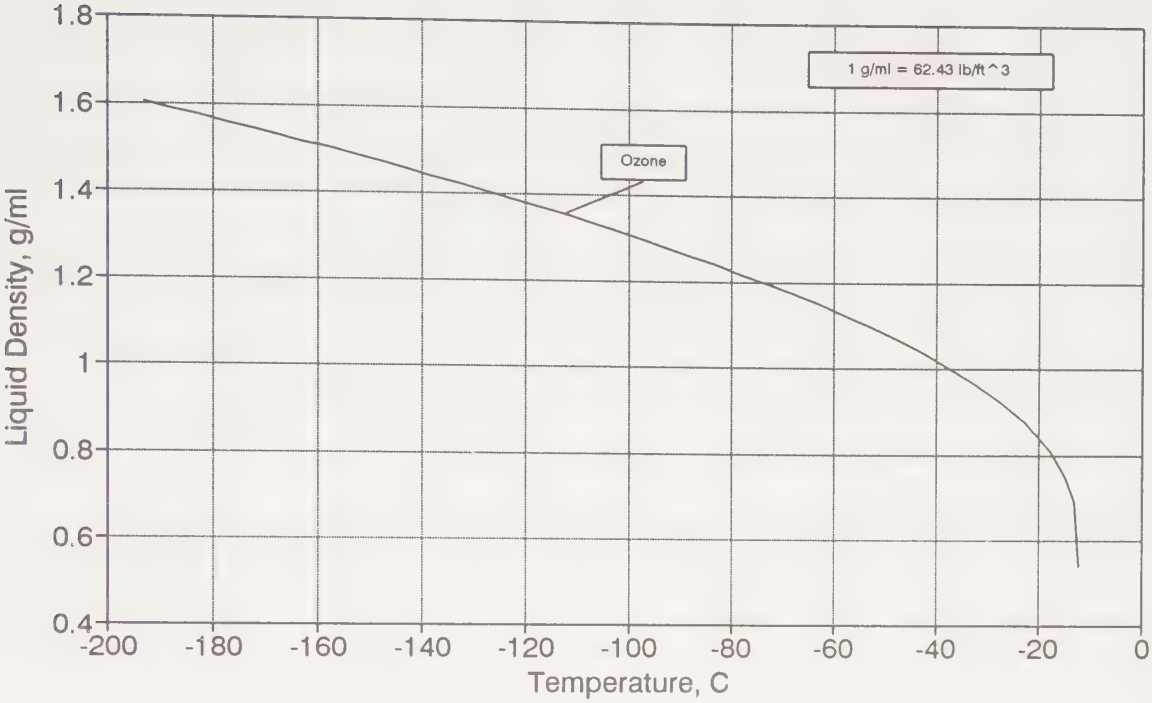

Figure 4-3 Liquid Density

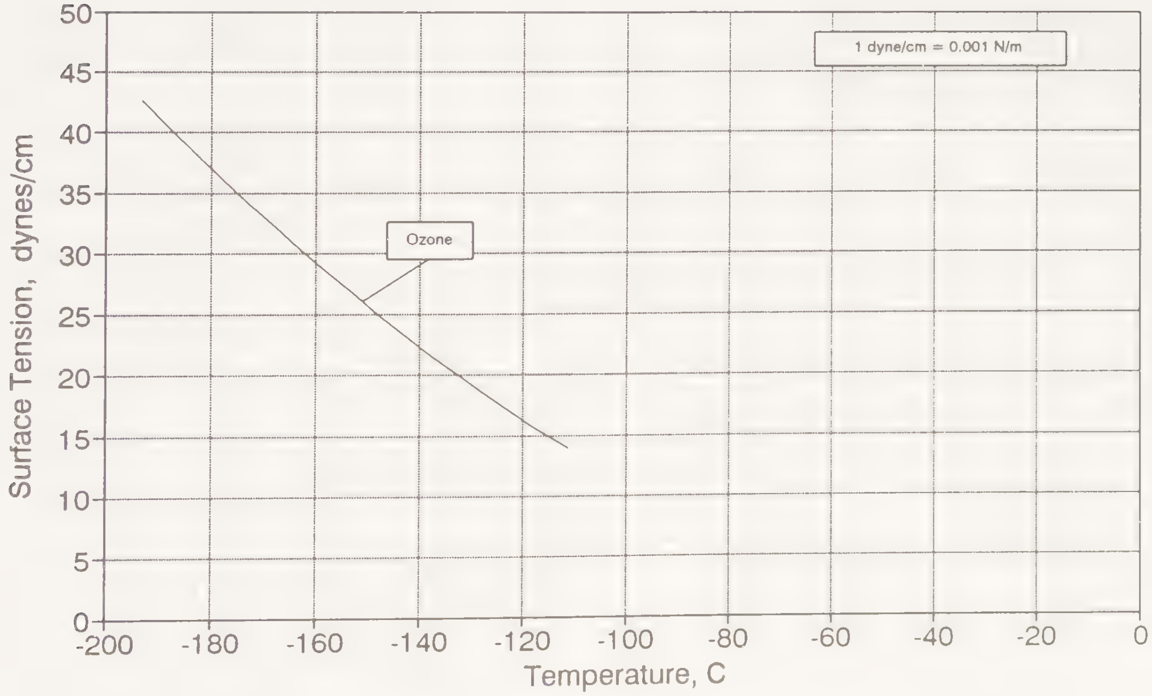

Figure 4-4 Surface Tension

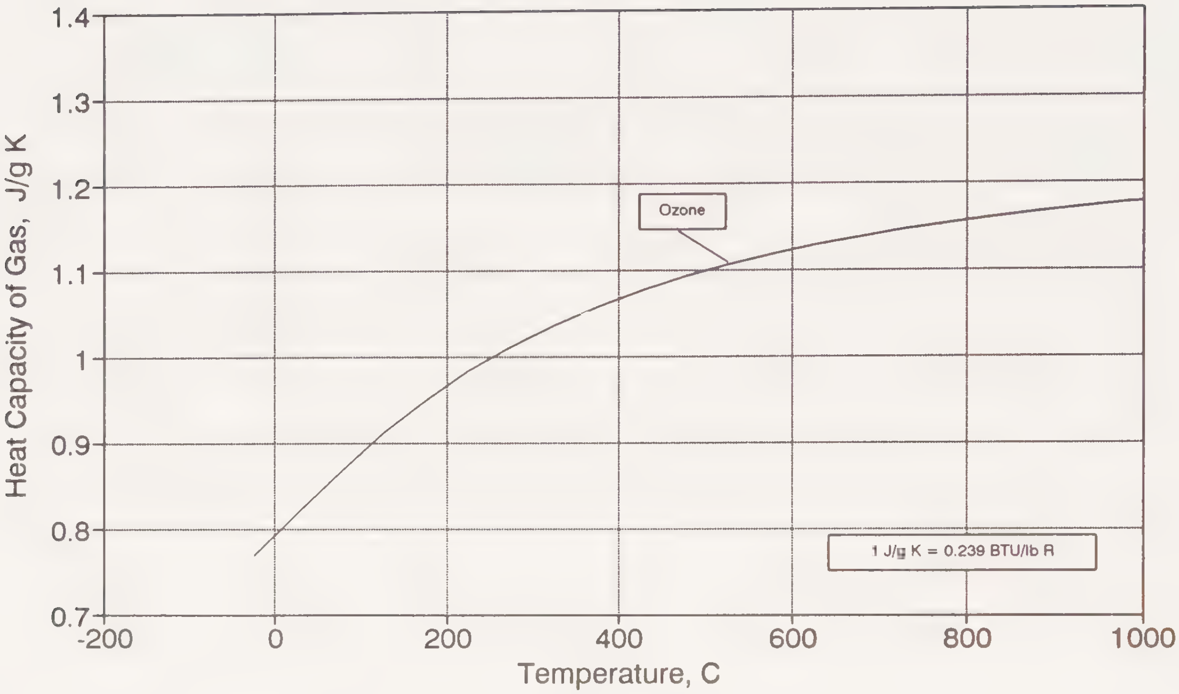

Figure 4-5 Heat Capacity of Gas

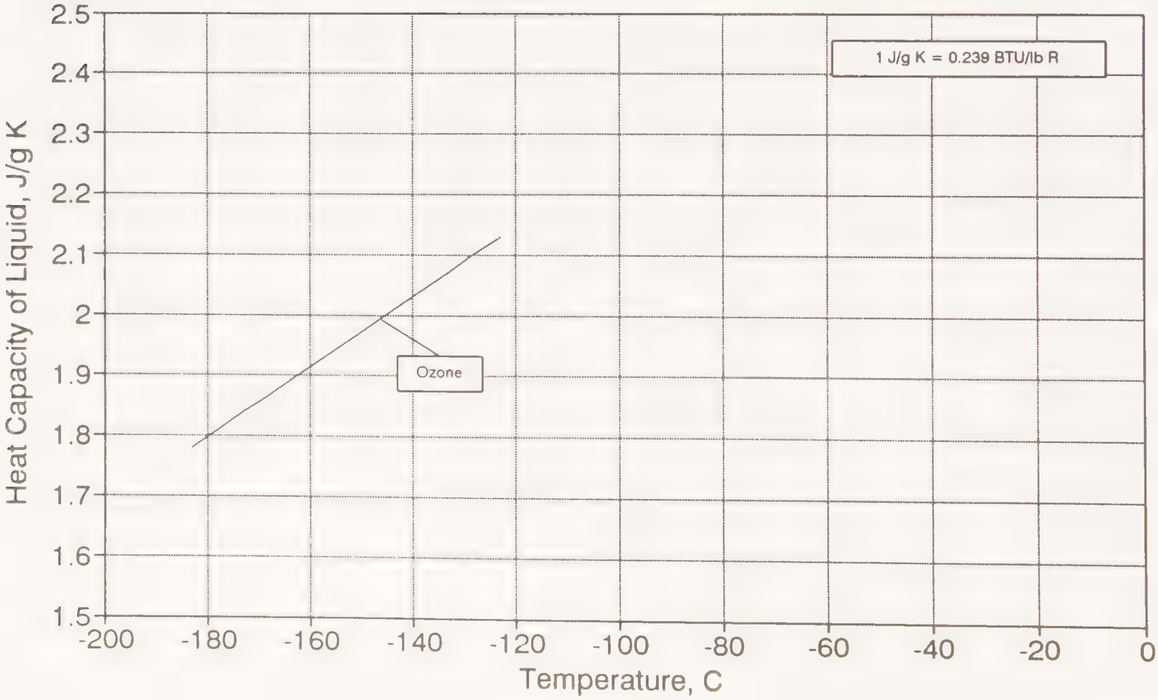

Figure 4-6 Heat Capacity of Liquid

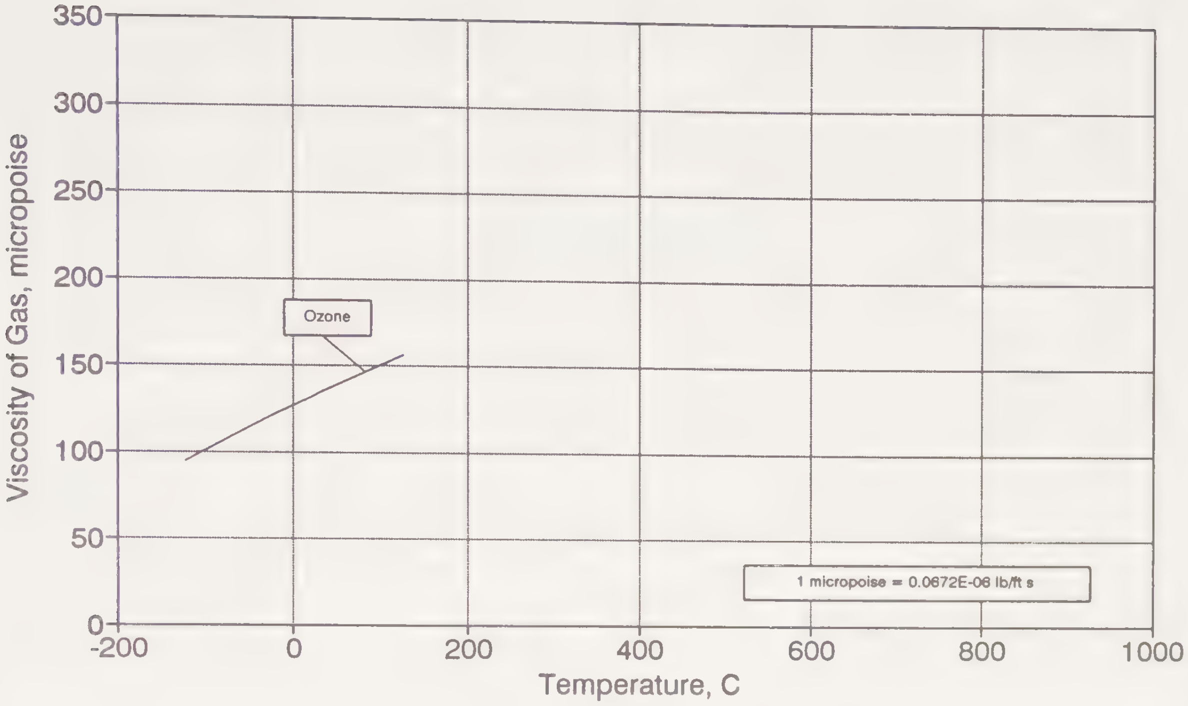

Figure 4-7 Viscosity of Gas

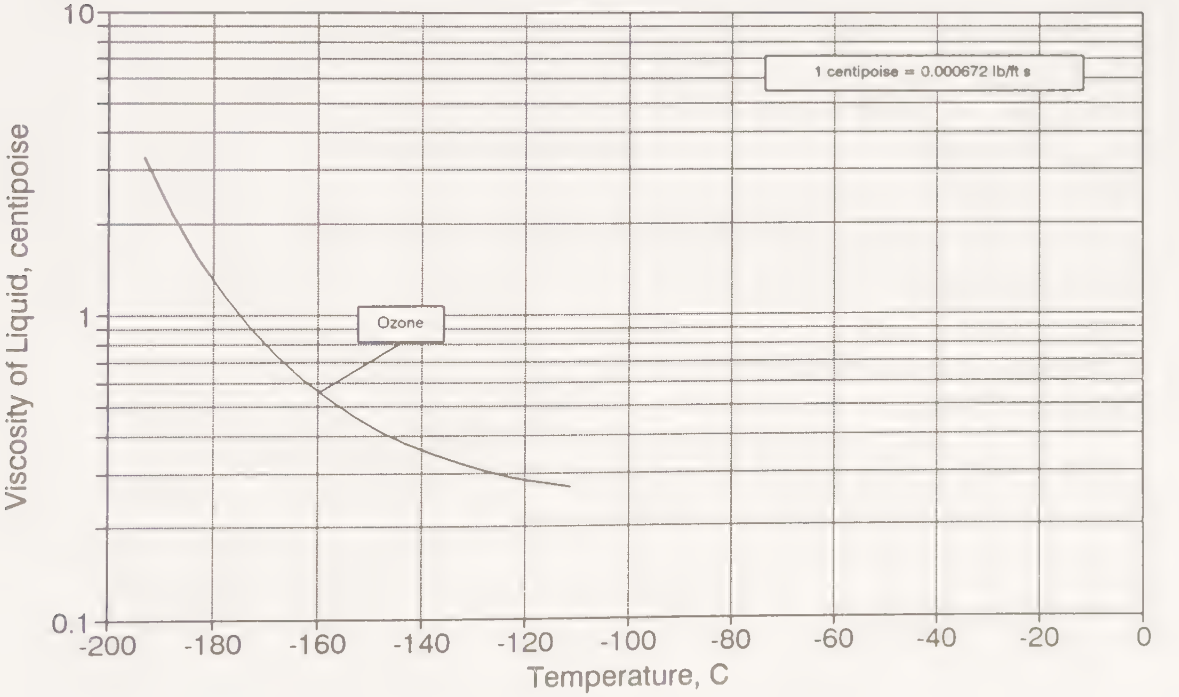

Figure 4-8 Viscosity of Liquid

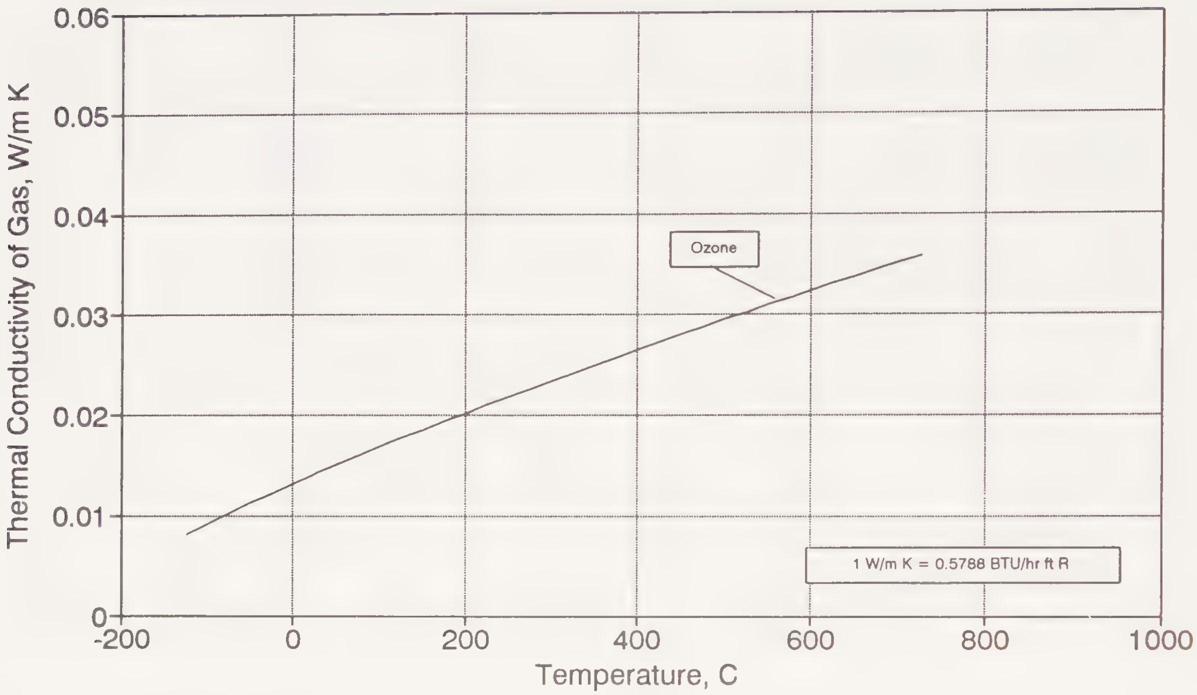

Figure 4-9 Thermal Conductivity of Gas

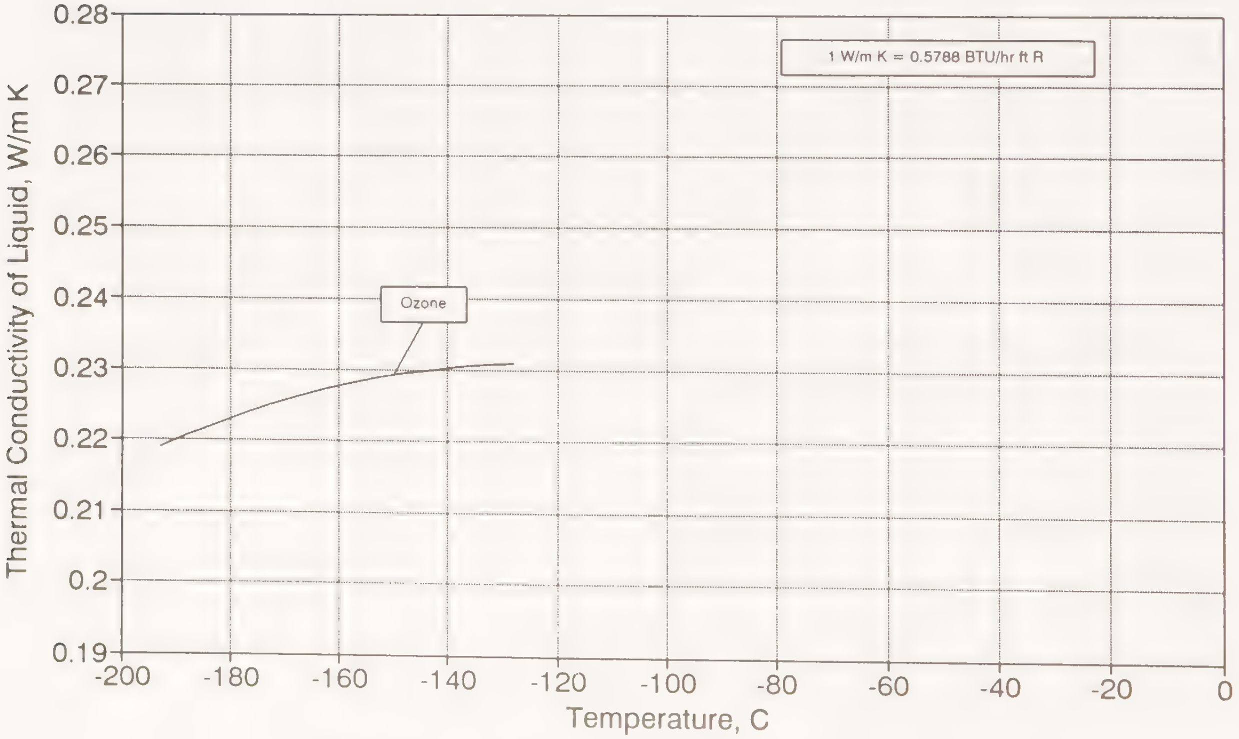

Figure 4-10 Thermal Conductivity of Liquid

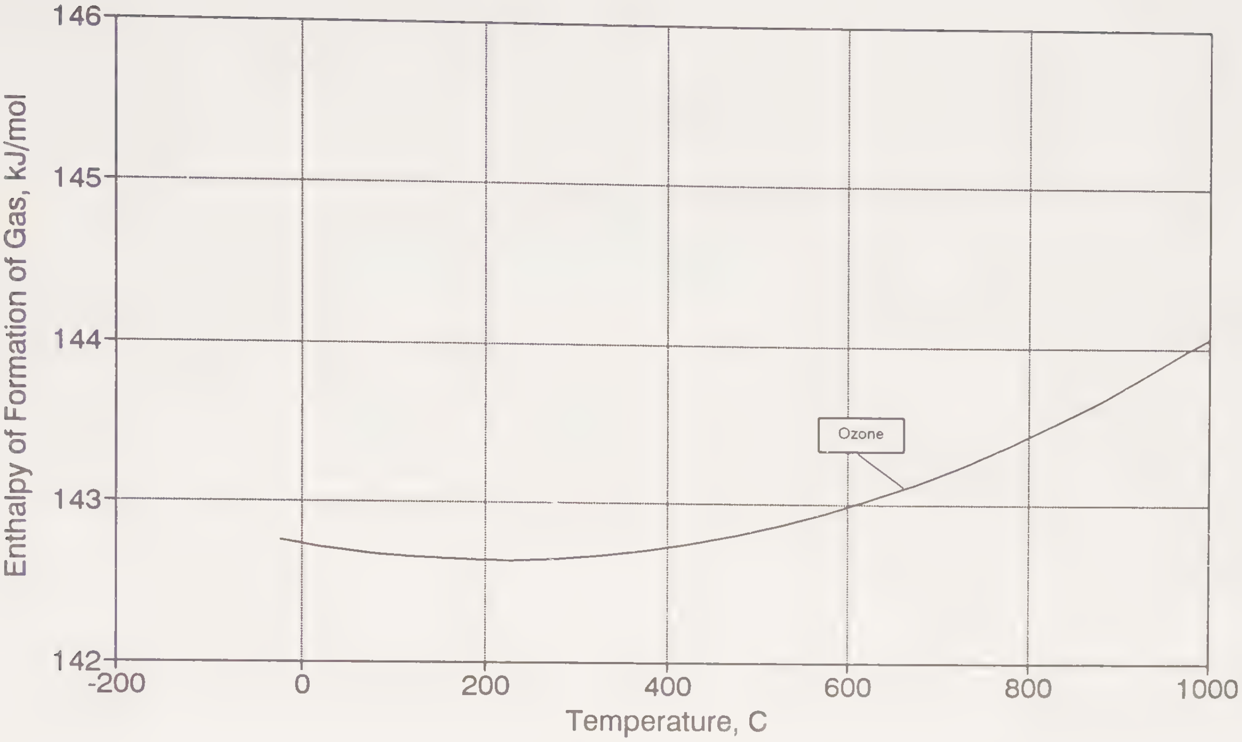

Figure 4-11 Enthalpy of Formation of Gas

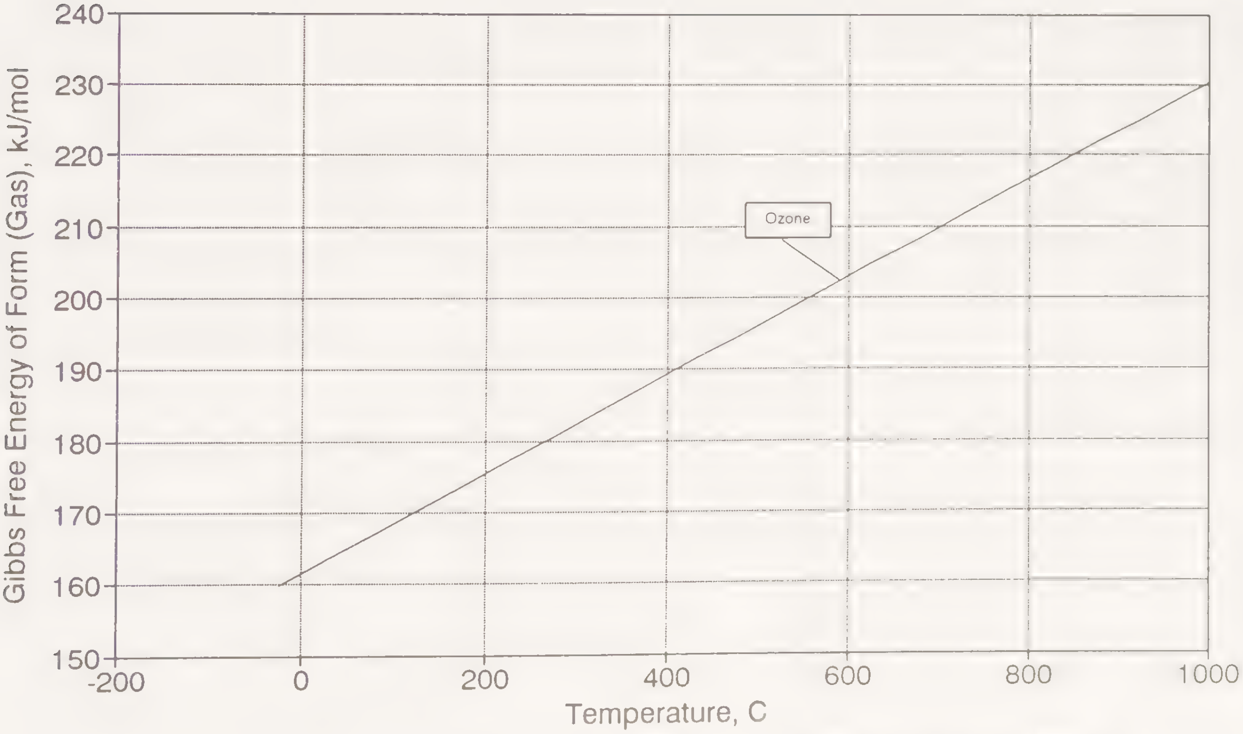

Figure 4-12 Gibbs Free Energy of Formation of Gas

Chapter 5

AMMONIA

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 5-1

Property data from the literature (1-27,31,33,34,36,37,39,42,108-111) are given in Table 5-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and data compilations by Yaws and co-workers (31) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 5-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 1% or less in most cases.

HEAT OF VAPORIZATION - Figure 5-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 5-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 1% in most cases.

SURFACE TENSION - Figure 5-4

Results from the DIPPR project (5) were selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 5-5 and 5-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The temperature range of coverage was extended using thermodynamic principles. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 3% or less using the correlation.

VISCOSITY - Figures 5-7 and 5-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in agreement with data. Errors are about 10% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 5-9 and 5-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 5-11

Results from the DIPPR project (5) and JANAF tables (37,110) were selected for enthalpy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 5-12

Results from the DIPPR project (5) and JANAF tables (37,110) were selected for Gibb's free energy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-12). Results from the correlation are in favorable agreement with data.

Table 5-1 Physical Properties

1. Name	Ammonia
2. Formula	NH3
3. Molecular Weight, g/mol	17.030
4. Critical Temperature, K	405.65
5. Critical Pressure, bar	112.78
6. Critical Volume, ml/mol	72.47
7. Critical Compressibility Factor	0.242
8. Acentric Factor	0.252
9. Melting Point, K	195.41
10. Boiling Point @ 1 atm, K	239.72
11. Heat of Vaporization @ BP, kJ/kg	1369.84
12. Density of Liquid @ BP, g/ml	0.681
13. Surface Tension @ BP, dynes/cm	34.03
14. Heat Capacity of Gas @ 25 C, J/g K	2.094
15. Heat Capacity of Liquid @ BP, J/g K	4.436
16. Viscosity of Gas @ 25 C, micropoise	101.27
17. Viscosity of Liquid @ BP, centipoise	0.246
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0249
19. Thermal Conductivity of Liquid @ BP, W/m K	0.6131
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-45.94
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	-16.31
22. Flash Point, K	------
23. Autoignition Temperature, K	924.26
24. Lower Explosion Limit in Air, vol %	16.0
25. Upper Explosion Limit in Air, vol %	25.0
26. Solubility in Water @ 20 C	34.6 kg NH3/100 kg of solution

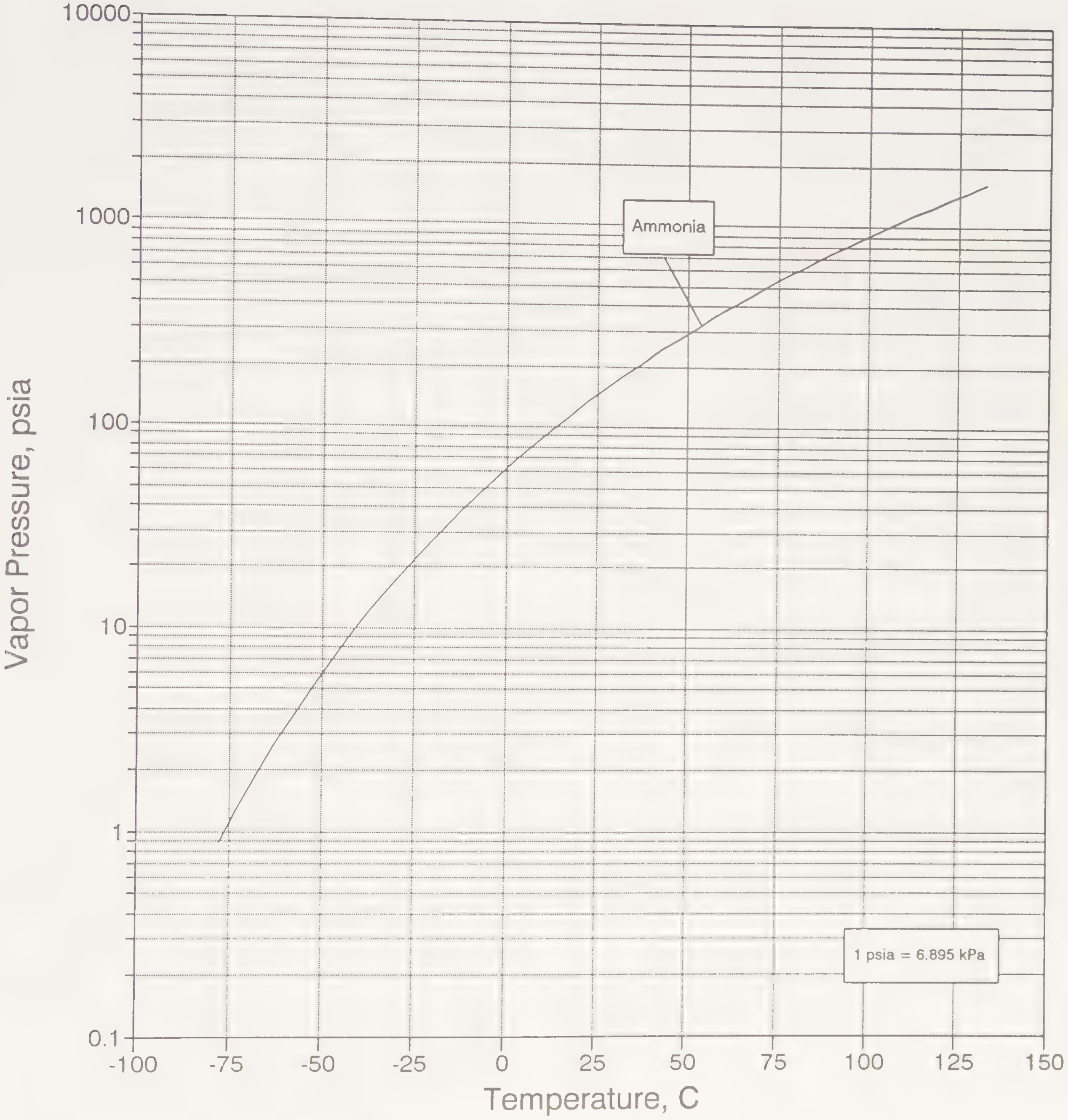

Figure 5-1 Vapor Pressure

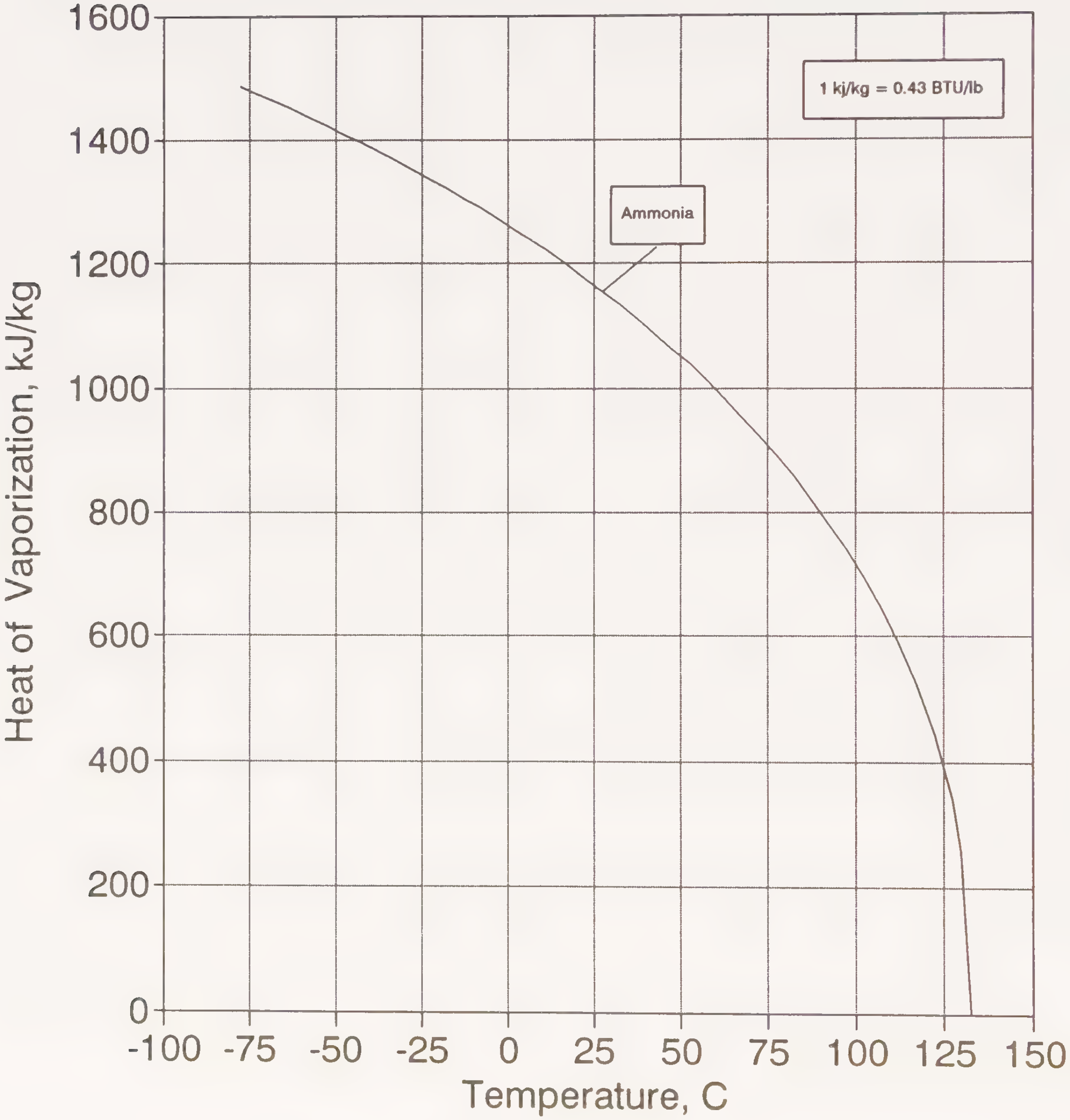

Figure 5-2 Heat of Vaporization

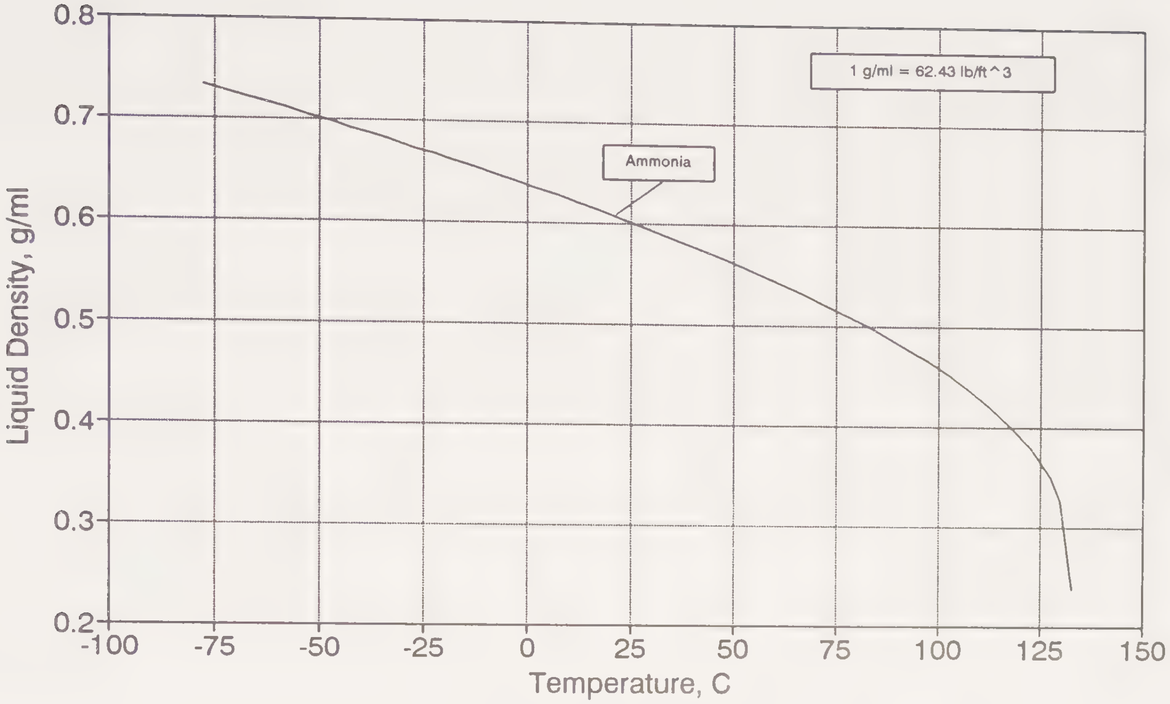

Figure 5-3 Liquid Density

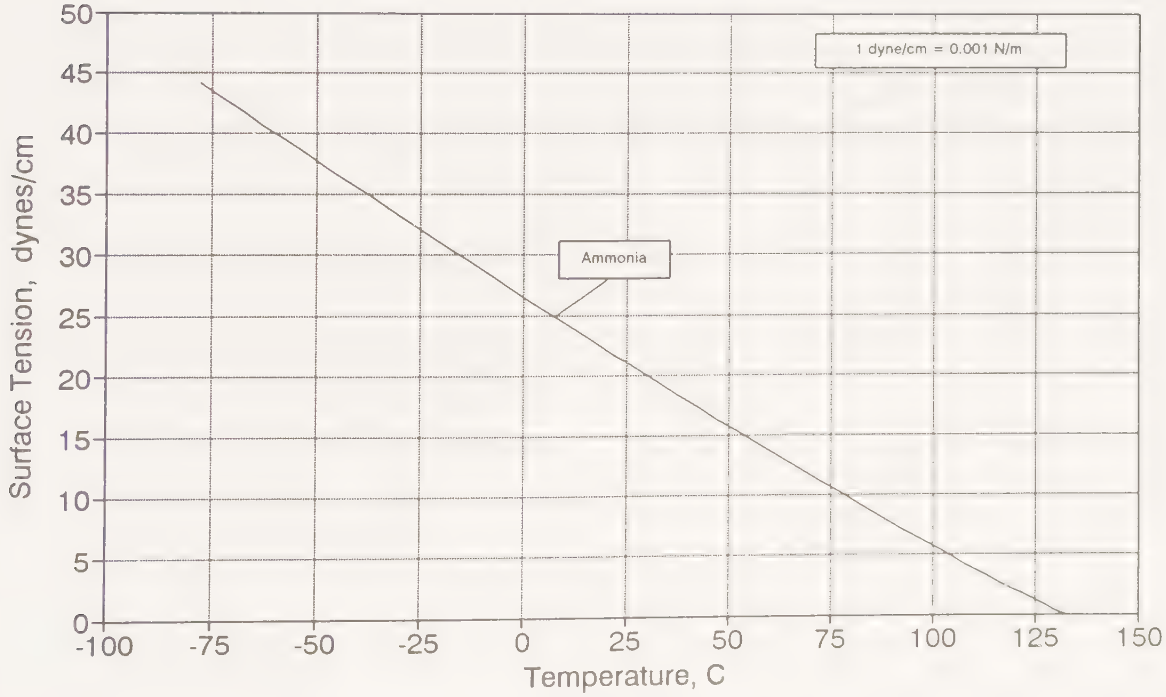

Figure 5-4 Surface Tension

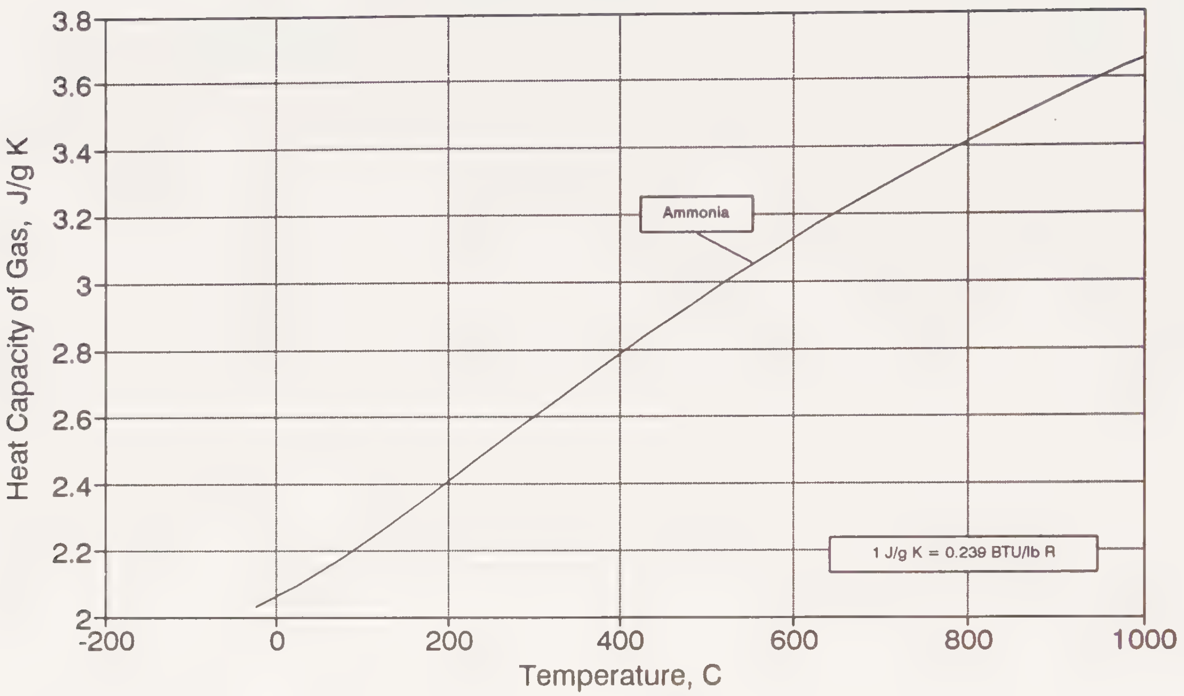

Figure 5-5 Heat Capacity of Gas

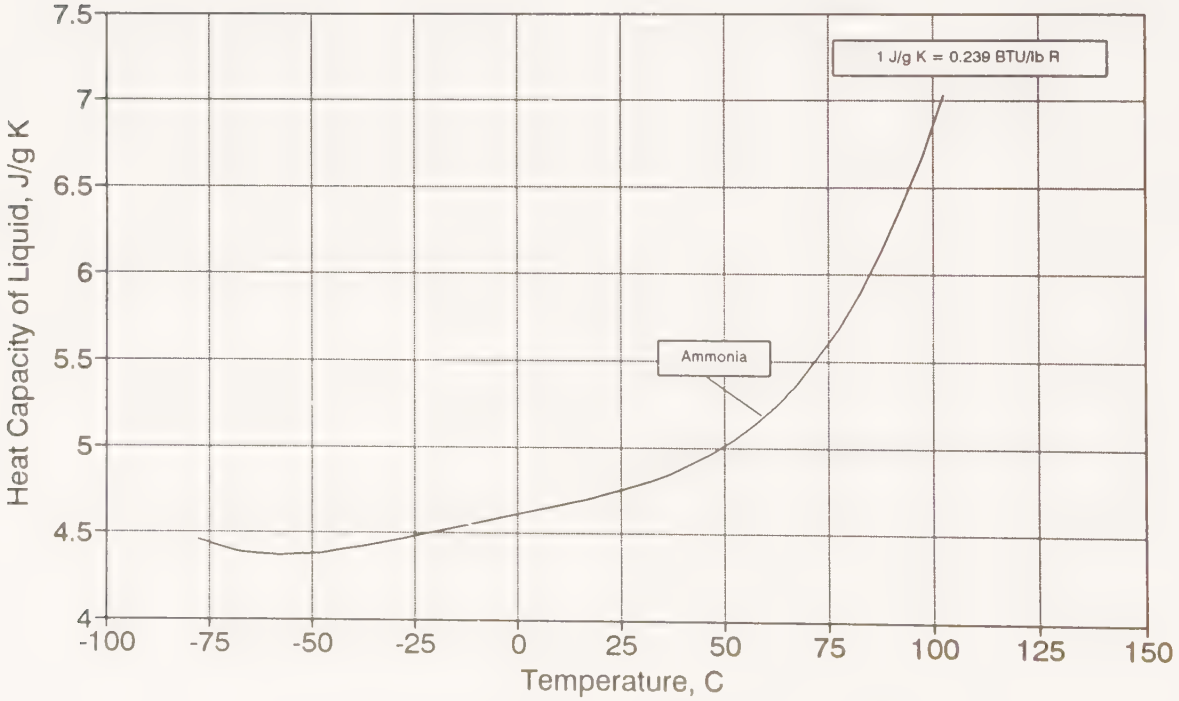

Figure 5-6 Heat Capacity of Liquid

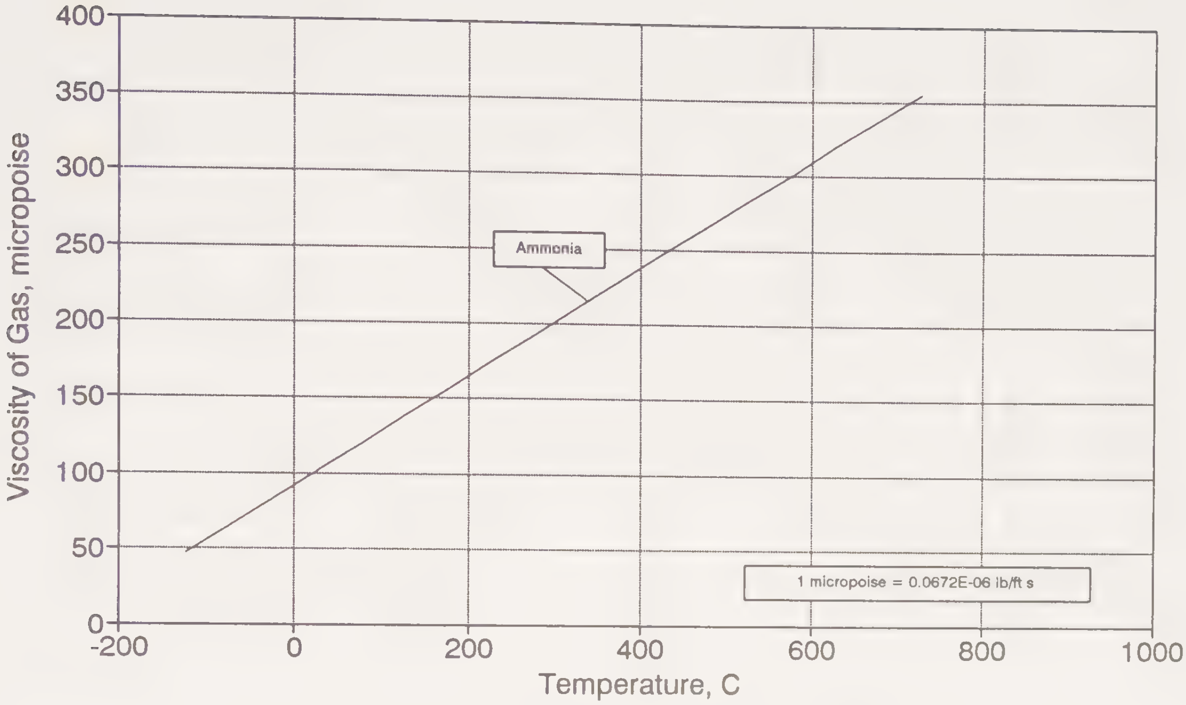

Figure 5-7 Viscosity of Gas

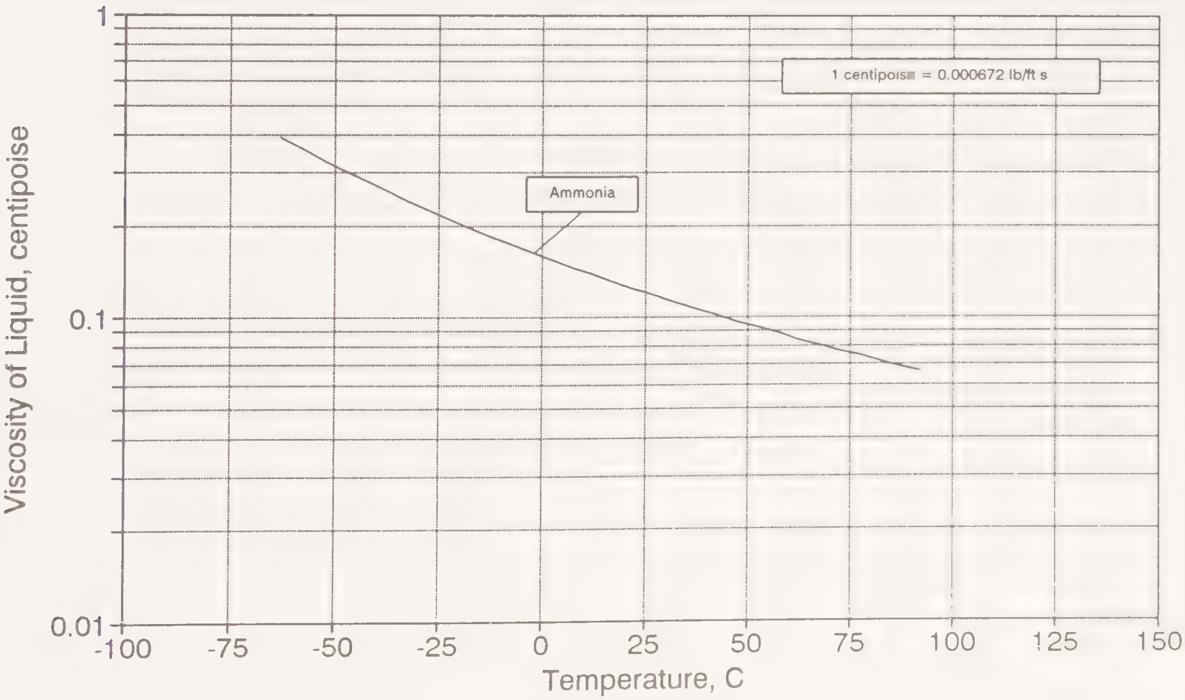

Figure 5-8 Viscosity of Liquid

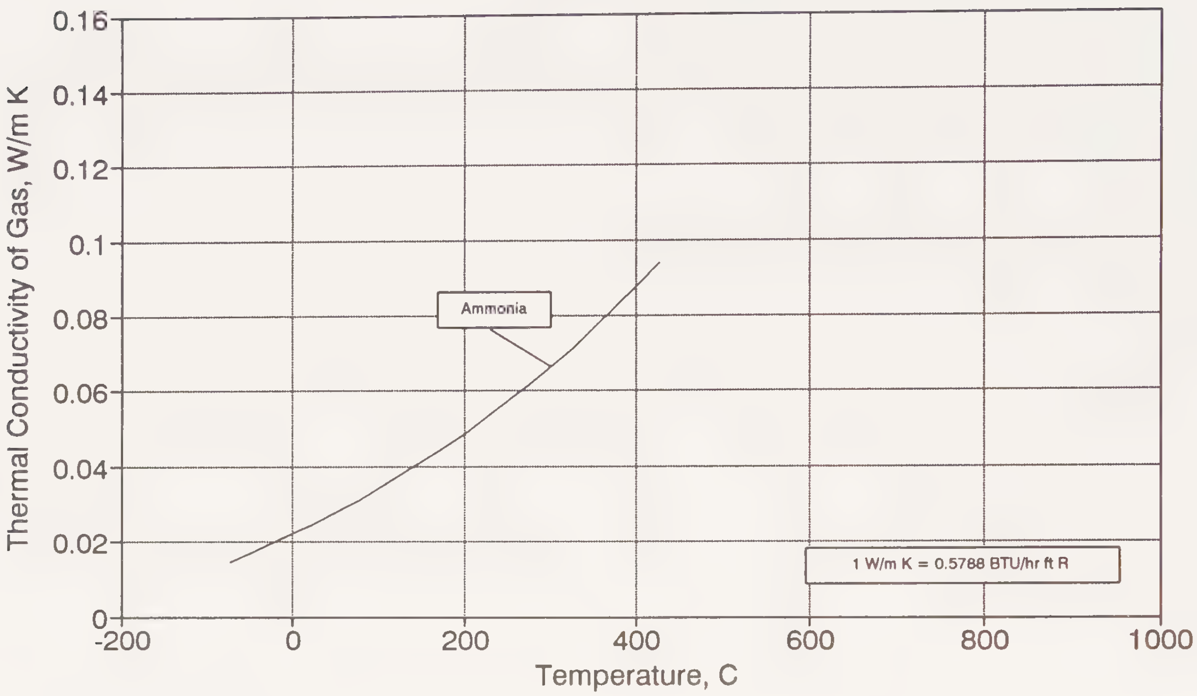

Figure 5-9 Thermal Conductivity of Gas

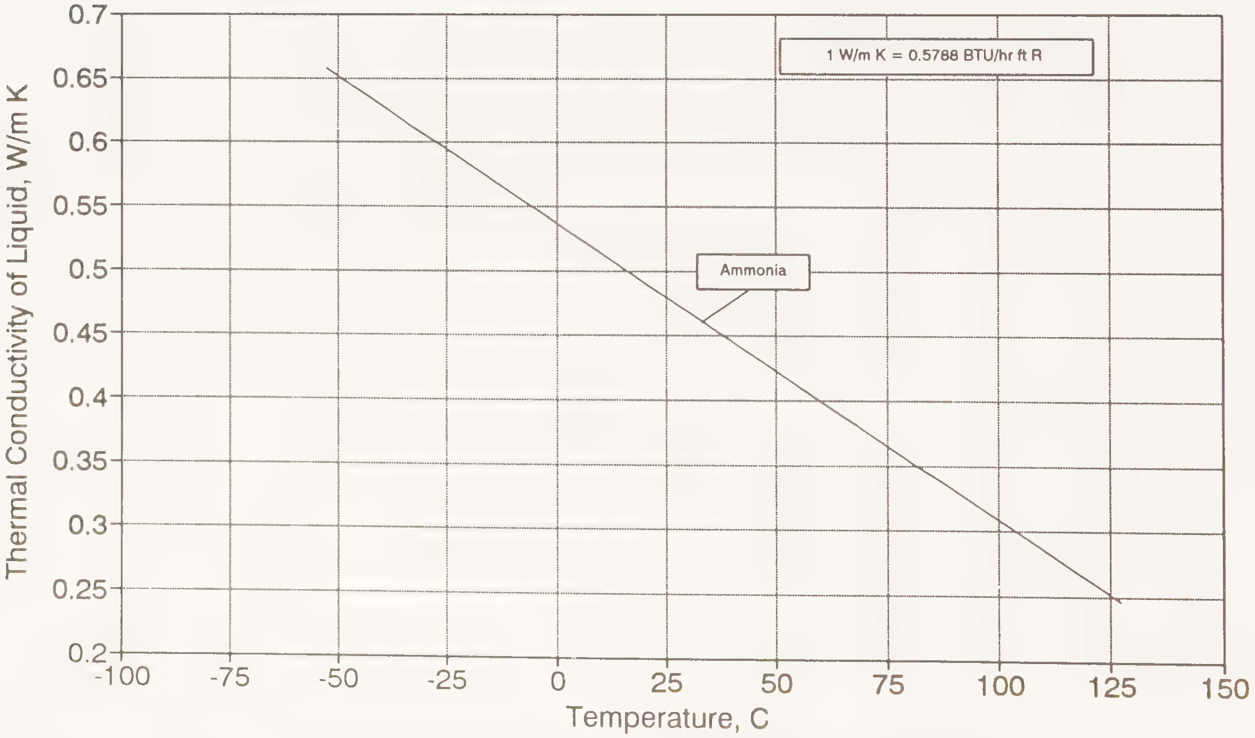

Figure 5-10 Thermal Conductivity of Liquid

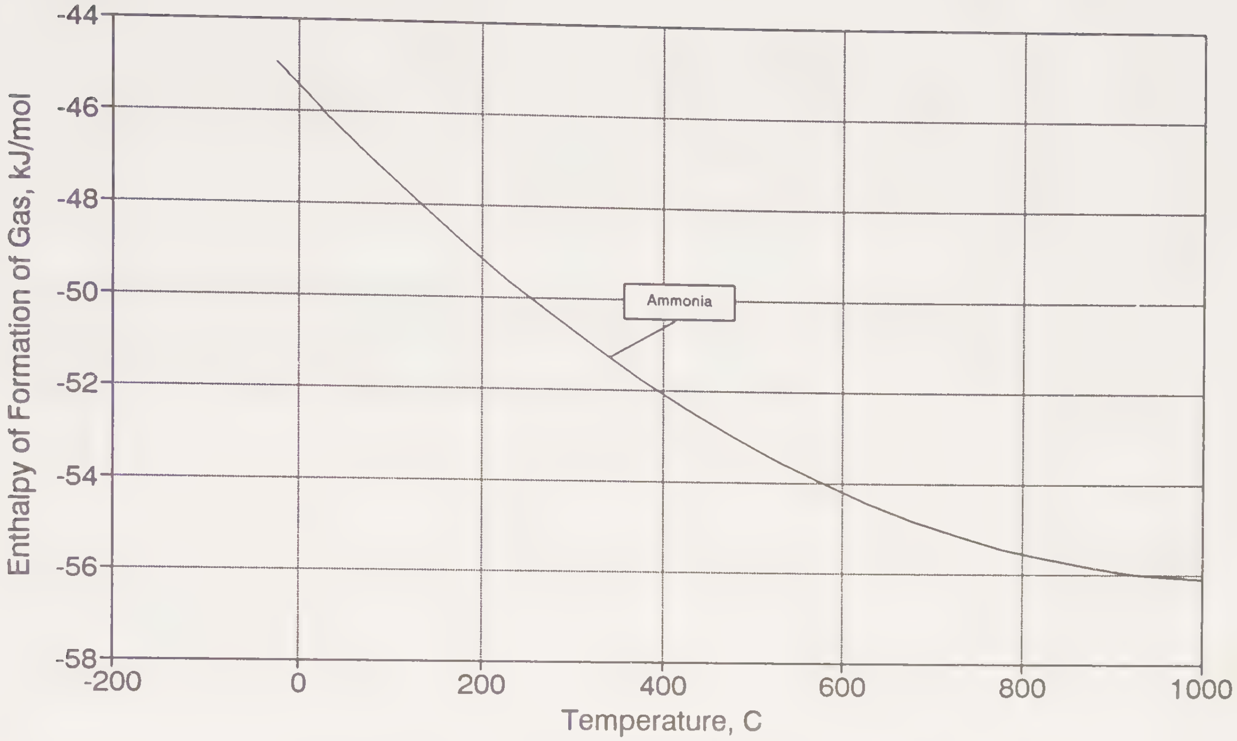

Figure 5-11 Enthalpy of Formation of Gas

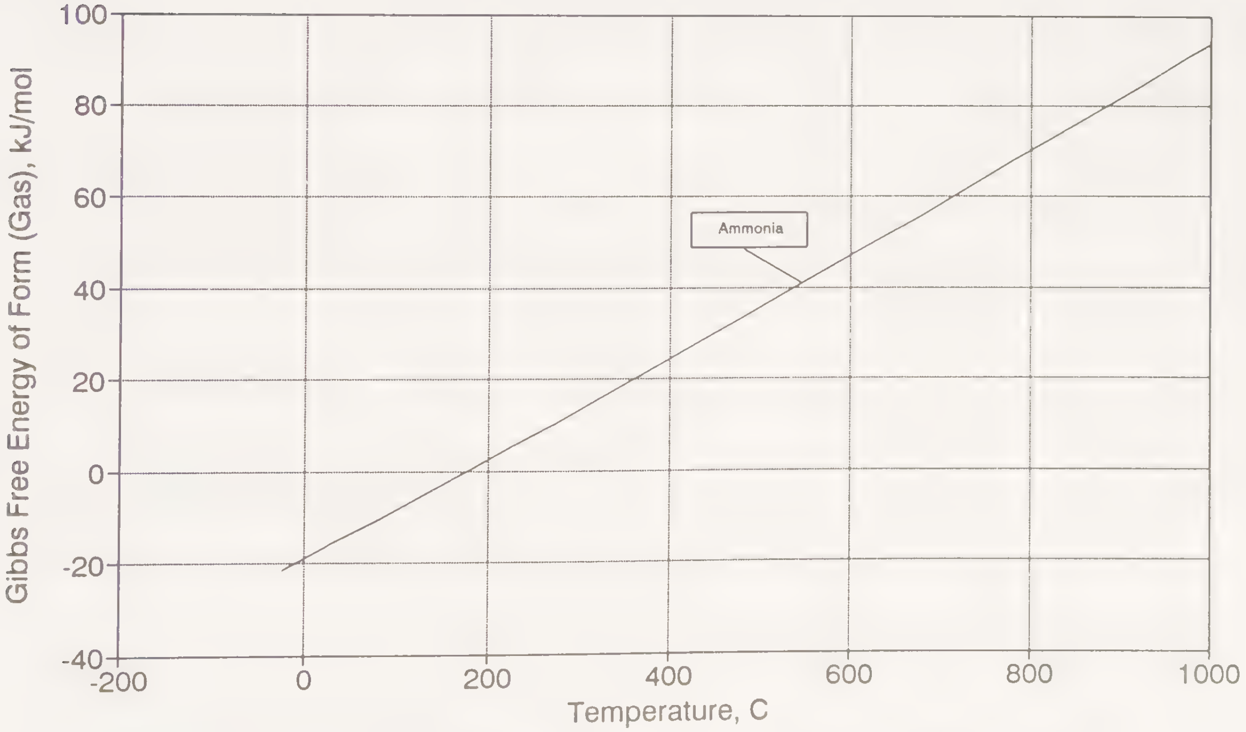

Figure 5-12 Gibbs Free Energy of Formation of Gas

Chapter 6

HYDROGEN AND HELIUM

Robert W. Gallant, Carl L. Yaws and William E. Simon

PHYSICAL PROPERTIES - Table 6-1

Property data from the literature (1-27,31,37-39,42,106,112-118,125-128) are given in Table 6-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5), data compilations by Yaws and co-workers (31) and MATHESON GAS DATA BOOK (13) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 6-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 5% or less in most cases.

HEAT OF VAPORIZATION - Figure 6-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 10% or less.

LIQUID DENSITY - Figure 6-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 6-4

Results from the DIPPR project (5) were selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 5% or less in most cases.

HEAT CAPACITY - Figures 6-5 and 6-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The temperature range of coverage was extended using thermodynamic principles. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 10% or less using the correlation.

VISCOSITY - Figures 6-7 and 6-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in agreement with data. Errors are about 10% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 6-9 and 6-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

SPECIAL NOTE

Hydrogen exists in two isomeric forms - ortho (parallel spin) in which the atomic nuclei spin in the same direction and para (anti-parallel spin) in which the nuclei spin in opposite directions. At ambient or higher temperatures, the equilibrium concentration of hydrogen is 75% ortho and 25% para. This 3/1 ratio is called "normal" hydrogen. The gas properties presented in this chapter apply to "normal" hydrogen which is of major industrial importance at ambient and higher temperatures.

When hydrogen gas at ambient or higher temperatures is quickly liquified by cooling, the liquid hydrogen is also 75% ortho-hydrogen. This liquid will slowly change to the para-form. The conversion is essentially complete at the boiling point with an equilibrium concentration of 99.8% para-hydrogen (25,26,31,125-128).

Liquid helium is also unique. When helium was first liquified in 1908, attempts to solidify the liquid were not successful even at 0.8 K (31,125). However, at a pressure of 41 bars, helium does solidify at 1.76 K (5). Also, as liquid helium is cooled to 2.2 K, a transition occurs forming a liquid called helium II. This transition (called the lambda point) marks the boundary between classical and quantum fluids. The properties of helium II are much different than those of helium I. In this chapter, property data for the liquid apply to 2.2 K and higher.

Table 6-1 Physical Properties

1. Name	Helium	Hydrogen
2. Formula	He	H2
3. Molecular Weight, g/mol	4.003	2.016
4. Critical Temperature, K	5.20	33.25
5. Critical Pressure, bar	2.275	12.97
6. Critical Volume, ml/mol	57.30	65.03
7. Critical Compressibility Factor	0.302	0.305
8. Acentric Factor	-0.3948	-0.2153
9. Melting Point, K	1.76 @ 41 bars	13.95
10. Boiling Point @ 1 atm, K	4.22	20.38
11. Heat of Vaporization @ BP, kJ/kg	20.84	441.60
12. Density of Liquid @ BP, g/ml	0.1239	0.0706
13. Surface Tension @ BP, dynes/cm	0.0959	1.935
14. Heat Capacity of Gas @ 25 C, J/g K	5.193	14.466
15. Heat Capacity of Liquid @ BP, J/g K	4.801	9.615
16. Viscosity of Gas @ 25 C, micropoise	198.69	88.65
17. Viscosity of Liquid @ BP, centipoise	0.00318	0.0132
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.1377	0.1718
19. Thermal Conductivity of Liquid @ BP, W/m K	0.0200	0.1204
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	------	------
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	------	------
22. Flash Point, K	------	------
23. Autoignition Temperature, K	------	673.15
24. Lower Explosion Limit in Air, vol %	------	4.0
25. Upper Explosion Limit in Air, vol %	------	75.0
26. Solubility in Water @ 20 C, ppm(wt)	1.43	1.47

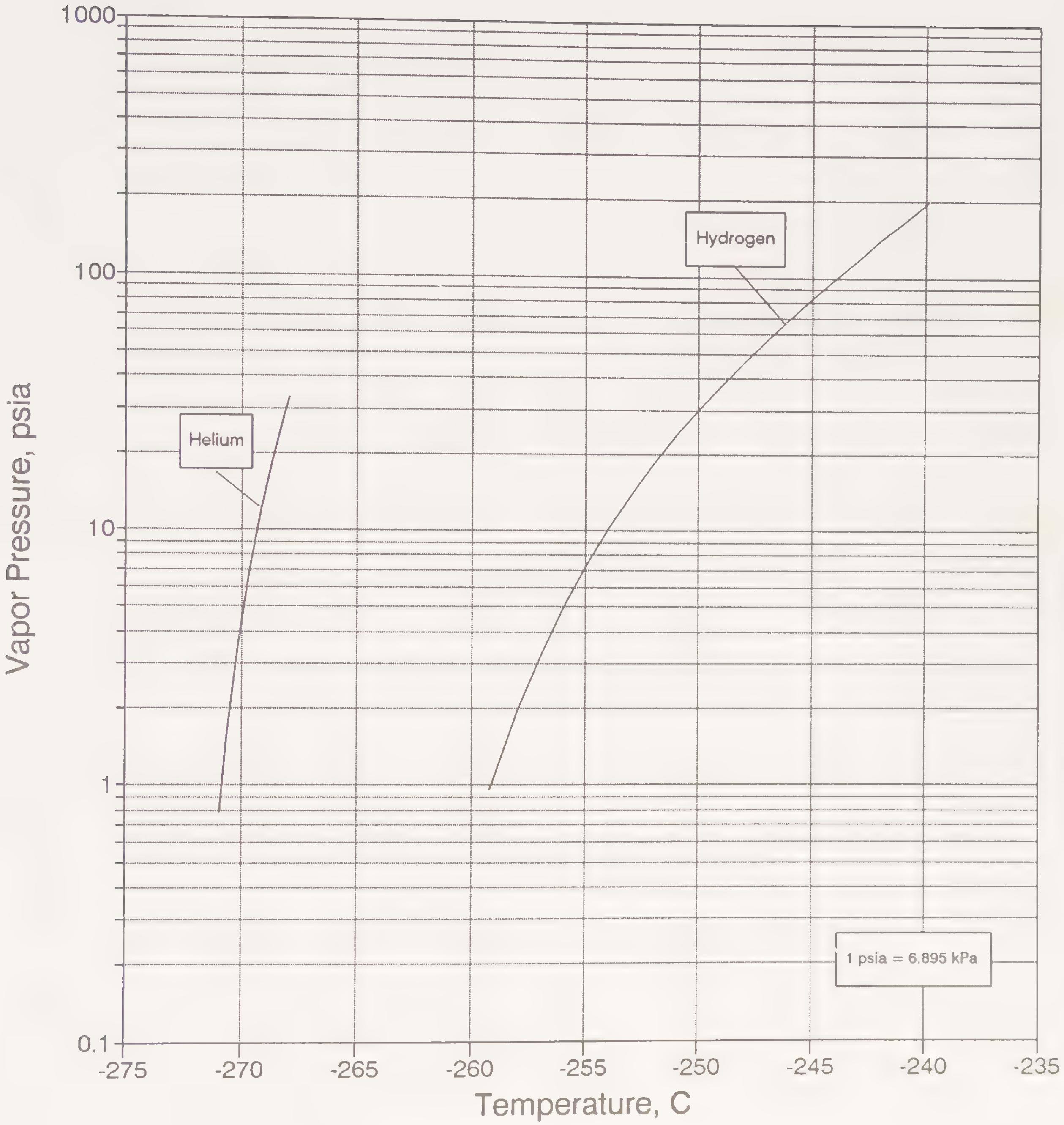

Figure 6-1 Vapor Pressure

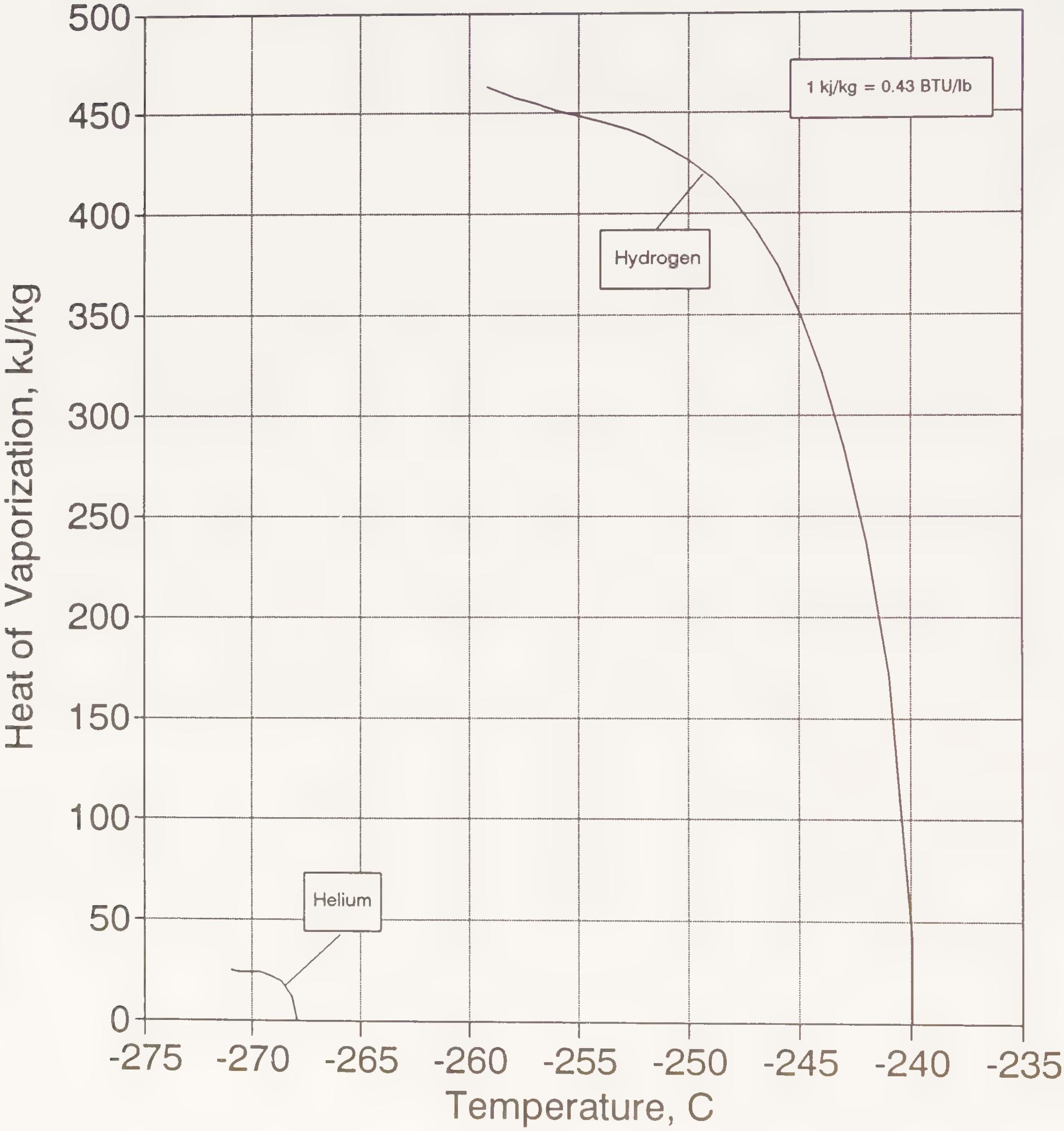

Figure 6-2 Heat of Vaporization

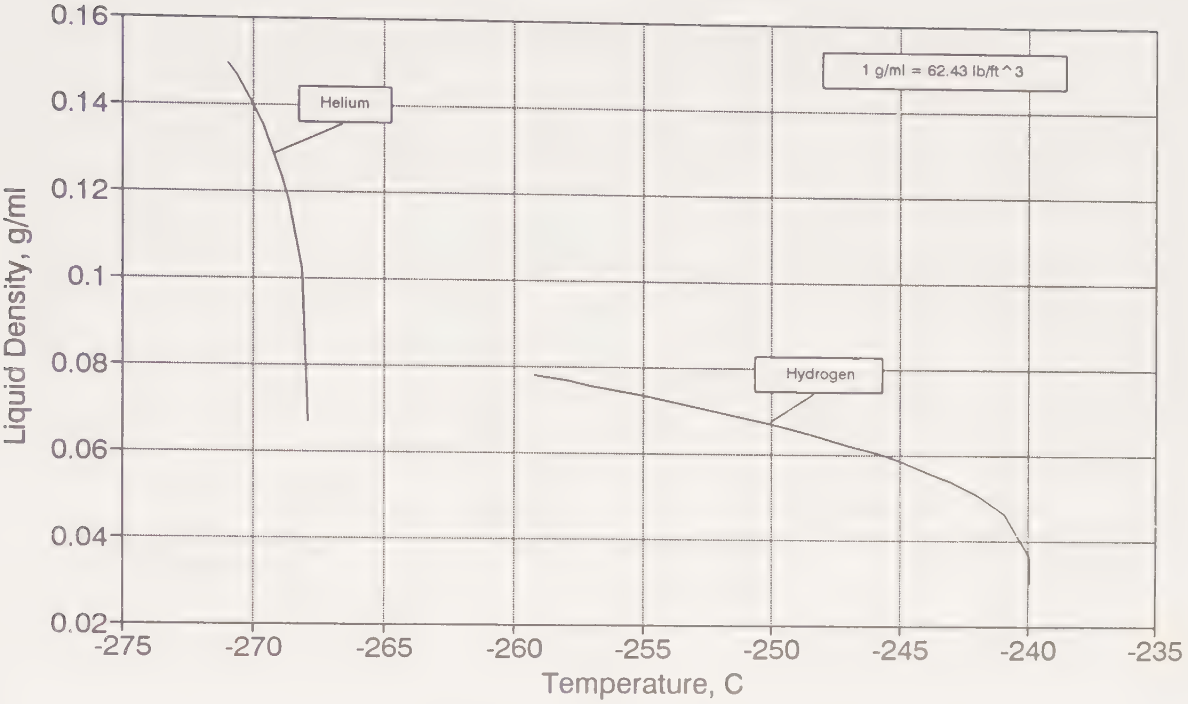

Figure 6-3 Liquid Density

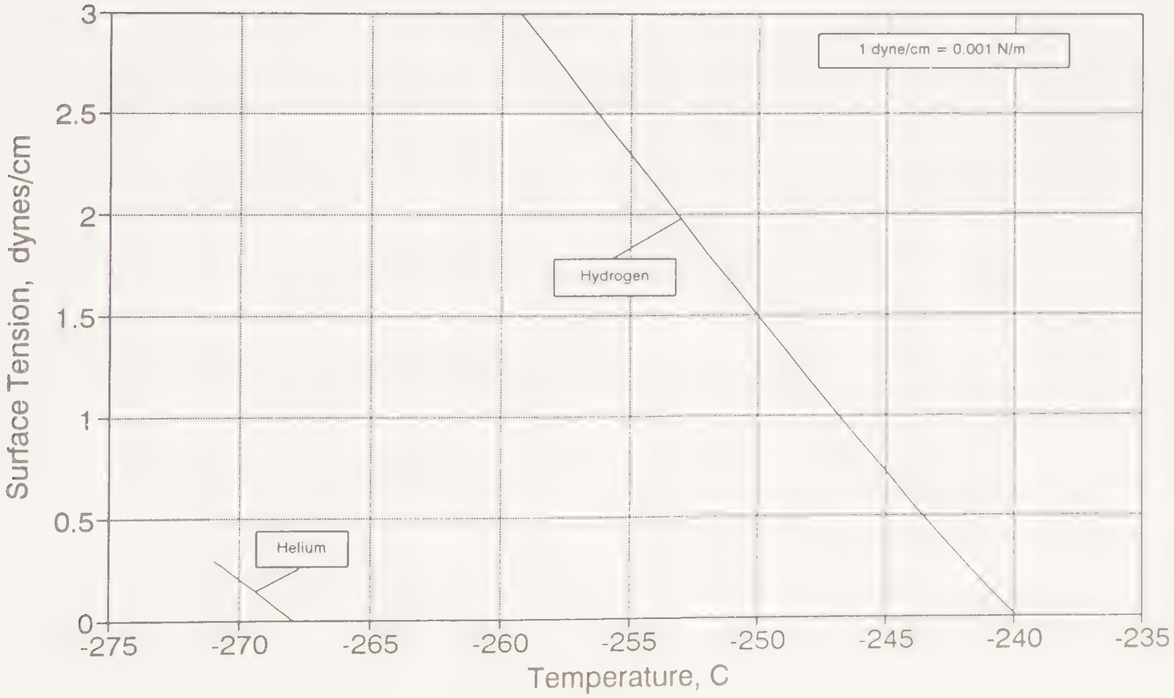

Figure 6-4 Surface Tension

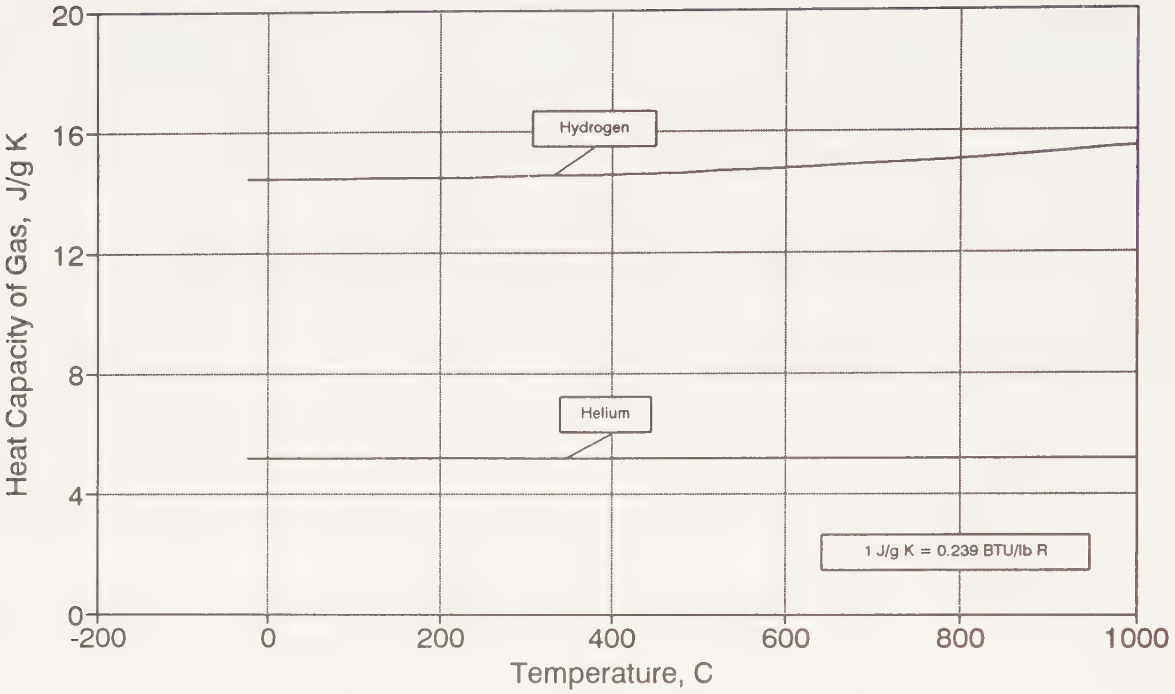

Figure 6-5 Heat Capacity of Gas

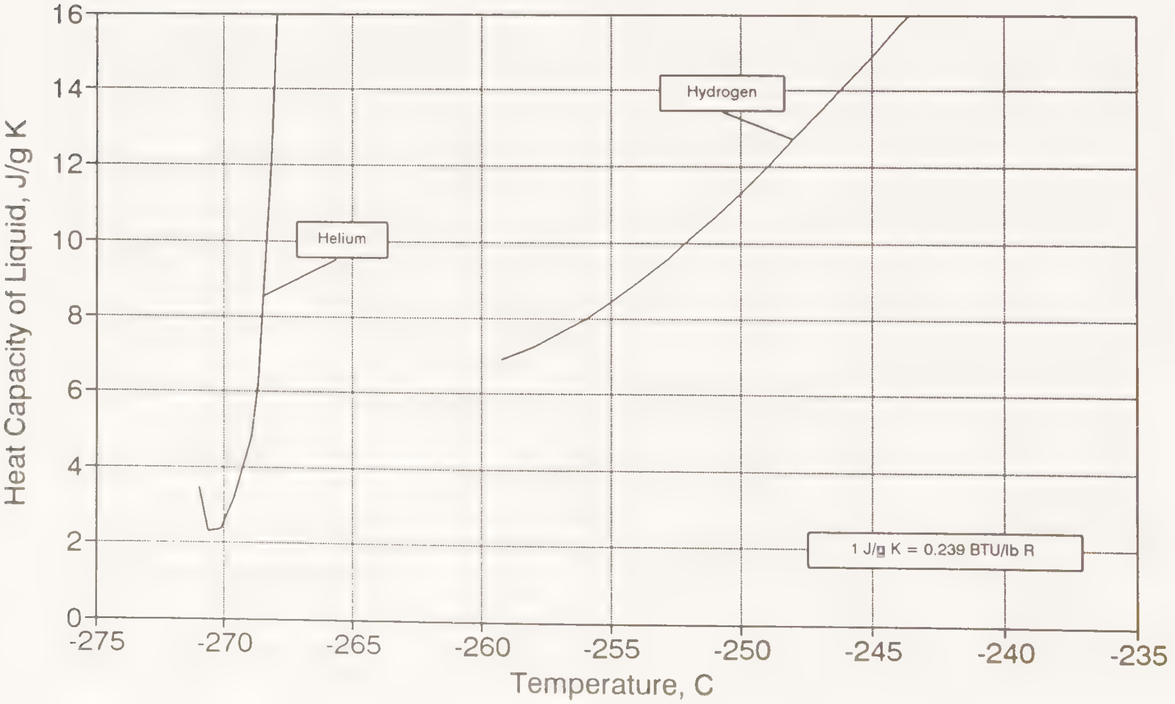

Figure 6-6 Heat Capacity of Liquid

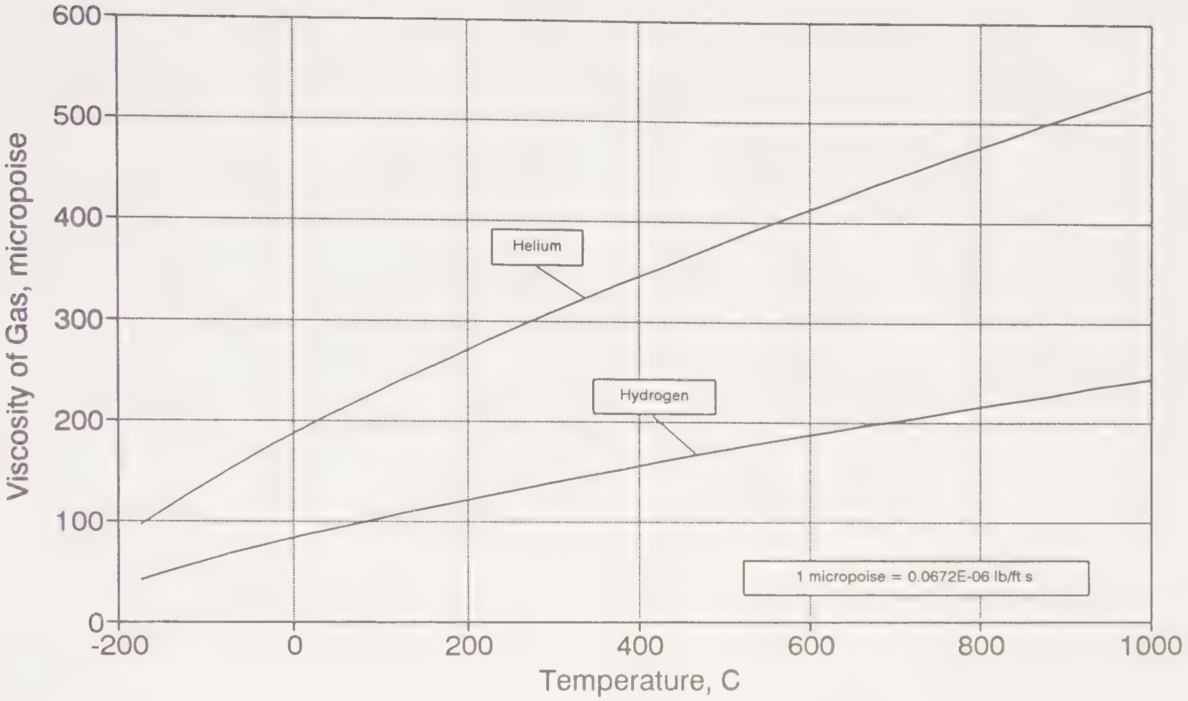

Figure 6-7 Viscosity of Gas

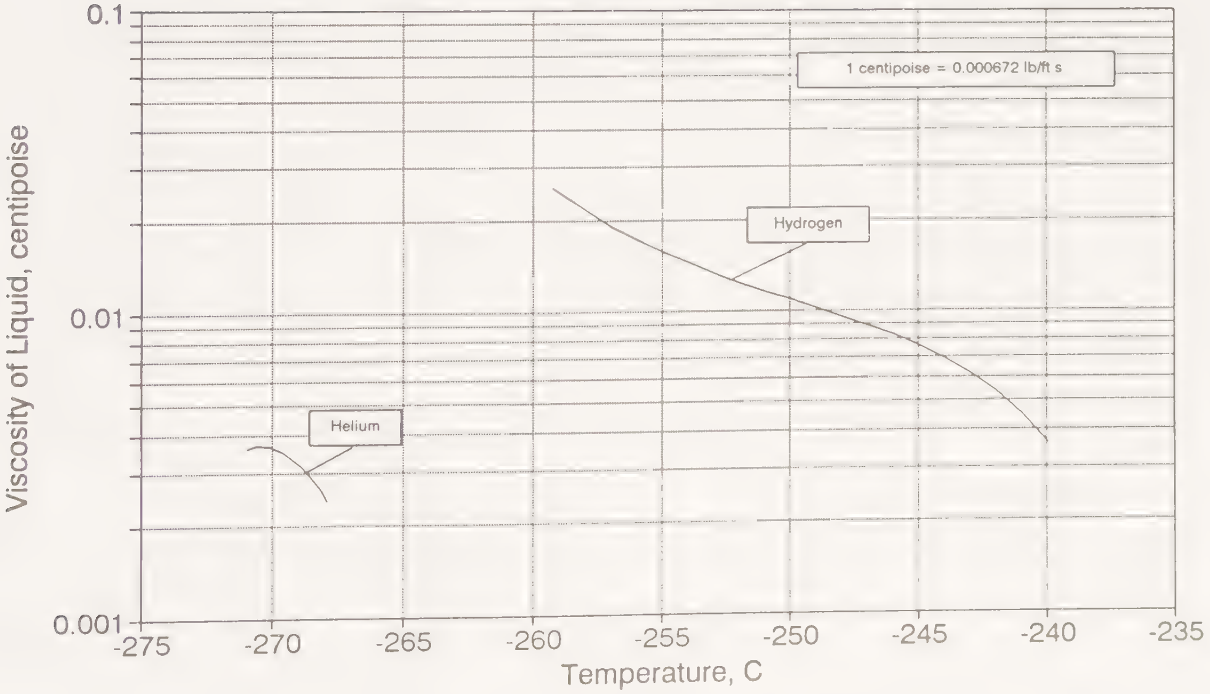

Figure 6-8 Viscosity of Liquid

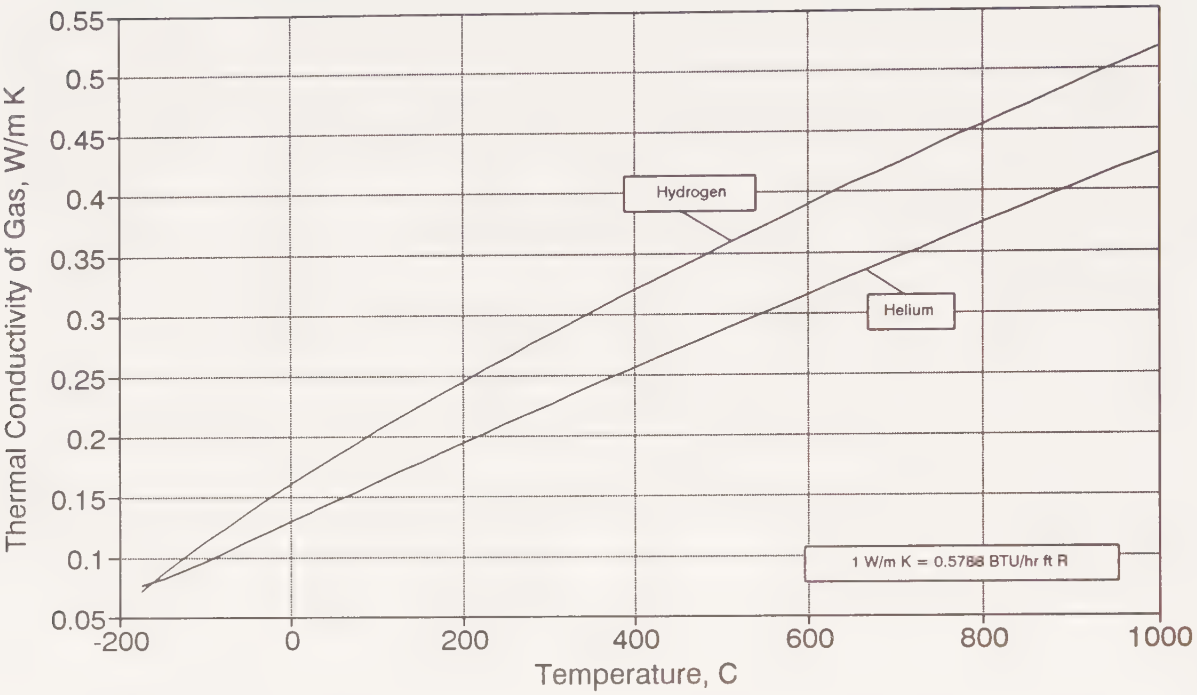

Figure 6-9 Thermal Conductivity of Gas

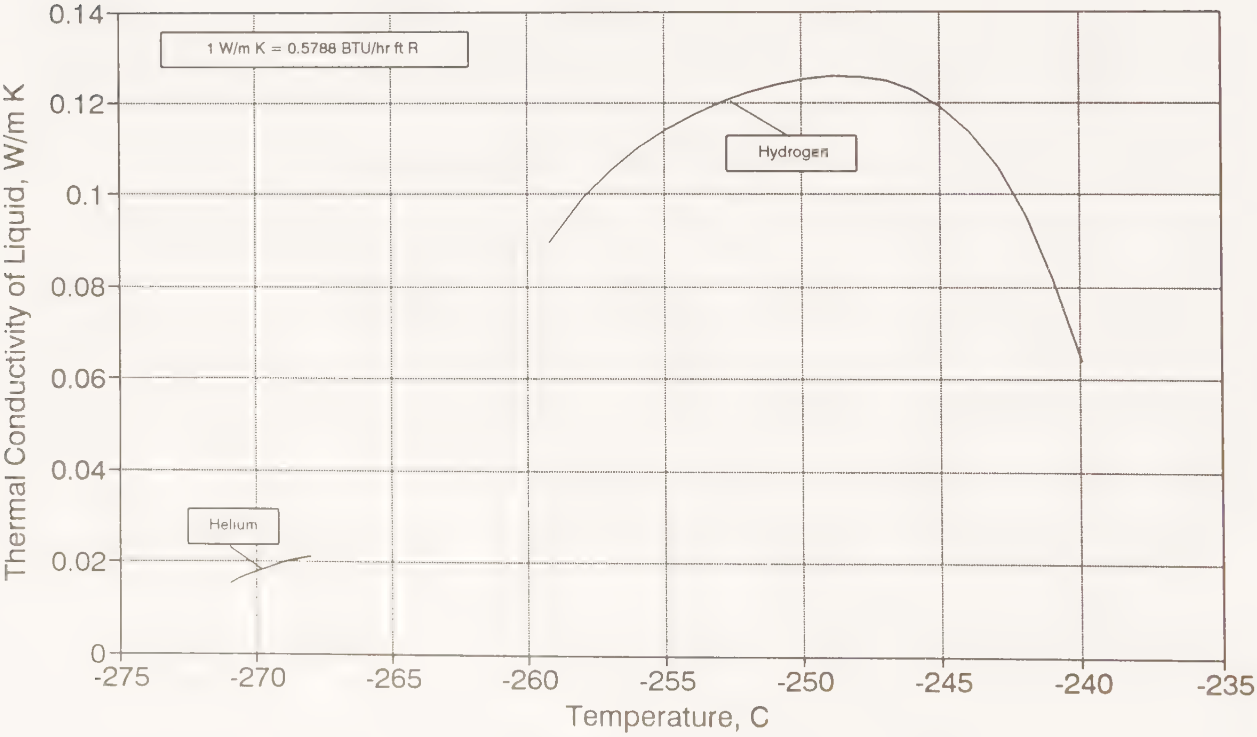

Figure 6-10 Thermal Conductivity of Liquid

Chapter 7

ARGON AND NEON

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 7-1

Property data from the literature (2-8,11,13-18,20-27,31,33,34,36,37,39,40,42,66,110,113,114,117,130-134) are given in Table 7-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and data compilations by Yaws and co-workers (31) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 7-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 7-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 1% or less.

LIQUID DENSITY - Figure 7-3

Results from the data compilations by Yaws and co-workers (31) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 1% in most cases.

SURFACE TENSION - Figure 7-4

Results from the DIPPR project (5) were selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 7-5 and 7-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The temperature range of coverage was extended using thermodynamic principles. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 7-7 and 7-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in agreement with data. Errors are about 10% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 7-9 and 7-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 1-10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases for argon. Reliability of results for Neon are not as good with possible errors of 50% or less.

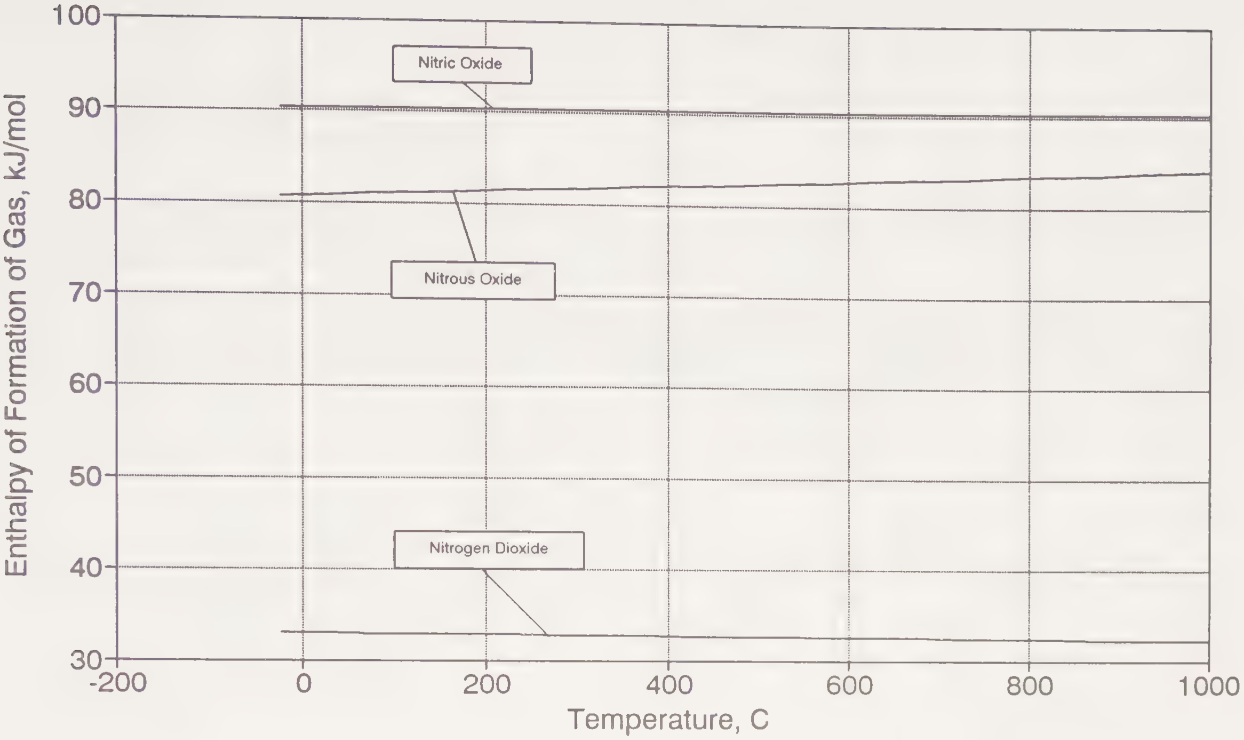

Figure 8-11 Enthalpy of Formation of Gas

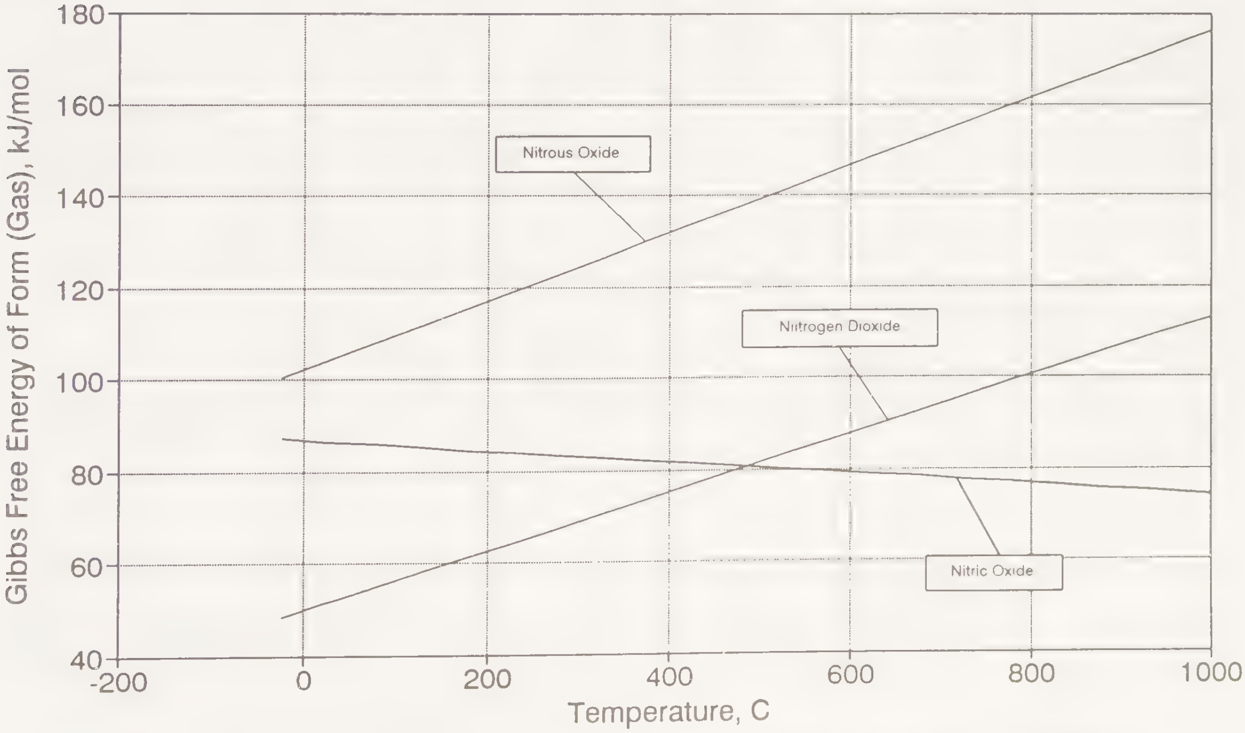

Figure 8-12 Gibbs Free Energy of Formation of Gas

Chapter 9

SULFUR OXIDES

Robert W. Gallant, Carl L. Yaws and K. Y. Li

PHYSICAL PROPERTIES - Table 9-1

Property data from the literature (2,3,5-8,11-18,20-27,31,37-39,106,135) are given in Table 9-1. The critical constants have been determined experimentally. Additional property data such as acentric factor, enthalpy of formation and solubility in water are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and data compilations by Yaws and co-workers (31) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 9-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 9-2

The DIPPR project (5) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 9-3

Results from the data compilation of Yaws and co-workers (31) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 5% in most cases.

SURFACE TENSION - Figure 9-4

The DIPPR project (5) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 9-5 and 9-6

Results from the data compilation of Yaws and co-workers (31) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (31) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 9-7 and 9-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in agreement with data. Errors are about 10% or less in most cases.

The data compilation of Yaws and co-workers (31) was selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using a modified de Guzman - Andrade equation, Equation (1-8a). Correlation results and data are in agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 9-9 and 9-10

The DIPPR project (5) was selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using Equation (1-9). Reliability of results is rough with errors of about 25% or less in most cases.

The DIPPR project (5) was selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 9-11

Results fron the DIPPR project (5) and the data compilation of Yaws and co-workers (31) were selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). The vertical shift in each curve at 444.6 C reflects the change in the standard reference state of elemental sulfur from the liquid to the gas (diatomic). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 9-12

Results fron the DIPPR project (5) and the data compilation of Yaws and co-workers (31) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). The vertical shift in each curve at 444.6 C reflects the change in the standard reference state of elemental sulfur from the liquid to the gas (diatomic). Correlation results are in favorable agreement with data.

SPECIAL NOTE

For sulfur trioxide, there are three forms (alpha, beta and gamma) in the solid phase. On cooling, the gamma form (icelike crystals with a melting point of 16.8 C) is obtained. The beta form (feathery crystals with a melting point of 32.5 C) is formed when traces of sulfuric acid are present. Additional conversion may occur to the alpha form (abestoslike crystals with a melting point of 62.3 C). For commercial practice, formation of the higher melting forms is normally prevented by addition of inhibitors.

Table 9-1 Physical Properties

1. Name	Sulfur Dioxide	Sulfur Trioxide
2. Formula	SO2	SO3
3. Molecular Weight, g/mol	64.065	80.064
4. Critical Temperature, K	430.75	490.85
5. Critical Pressure, bar	78.841	82.073
6. Critical Volume, ml/mol	122.0	127.08
7. Critical Compressibility Factor	0.269	0.256
8. Acentric Factor	0.2451	0.4215
9. Melting Point, K	200.00	289.95
10. Boiling Point @ 1 atm, K	263.13	317.90
11. Heat of Vaporization @ BP, kJ/kg	385.38	508.46
12. Density of Liquid @ 25 C, g/ml	1.369	1.851
13. Surface Tension @ 25 C, dynes/cm	21.69	33.08
14. Heat Capacity of Gas @ 25 C, J/g K	0.623	0.632
15. Heat Capacity of Liquid @ 25 C, J/g K	1.378	3.209
16. Viscosity of Gas @ 25 C, micropoise	129.24	135.57
17. Viscosity of Liquid @ 25 C, centipoise	0.257	1.602
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0095	0.0110
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1957	0.2469
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-297.81	-396.19
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	-300.52	-371.17
22. Flash Point, K	------	------
23. Autoignition Temperature, K	------	------
24. Lower Explosion Limit in Air, vol %	------	------
25. Upper Explosion Limit in Air, vol %	------	------
26. Solubility in Water @ 20 C	11.28 kg SO2 per 100 kg water	------

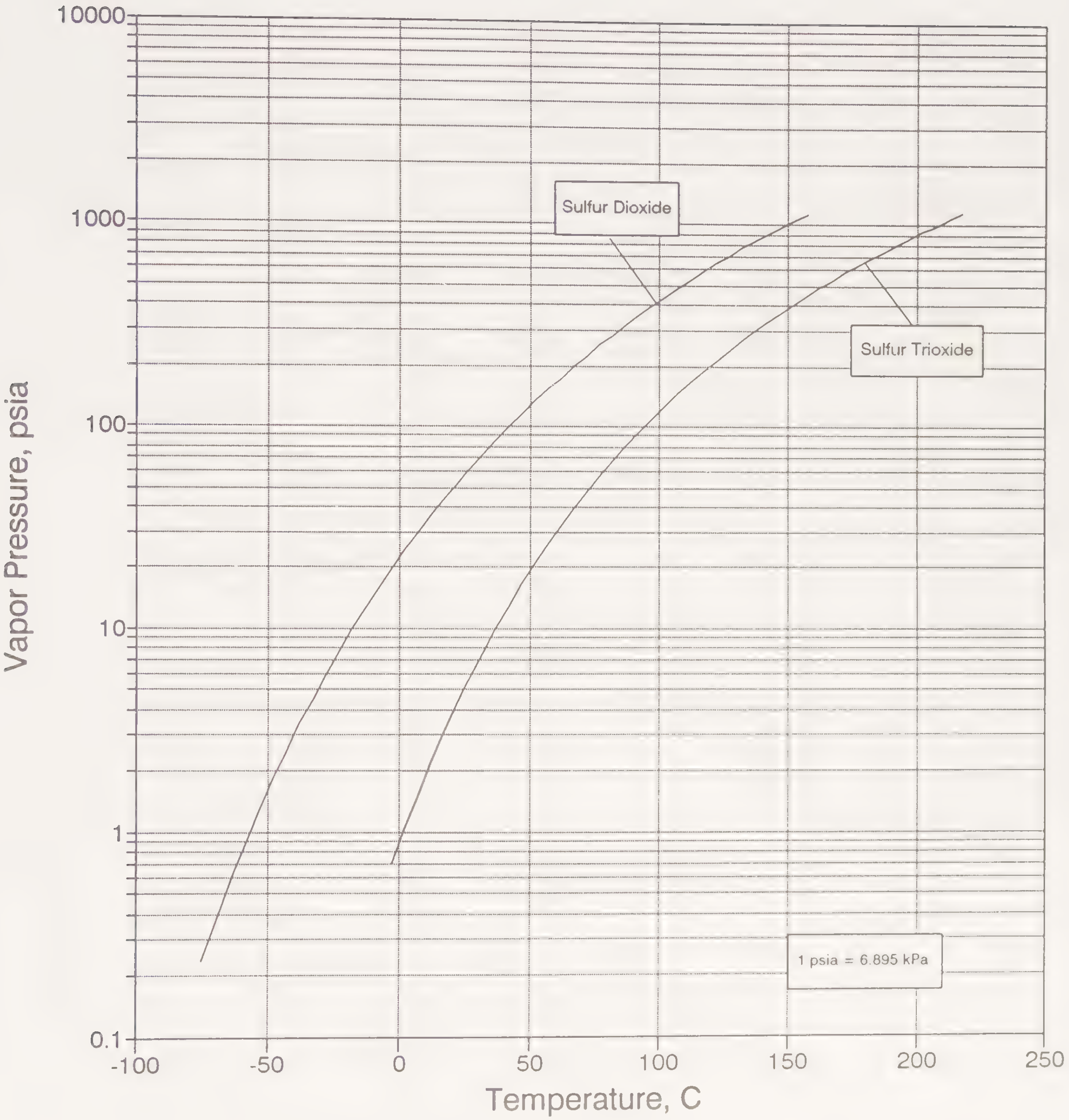

Figure 9-1 Vapor Pressure

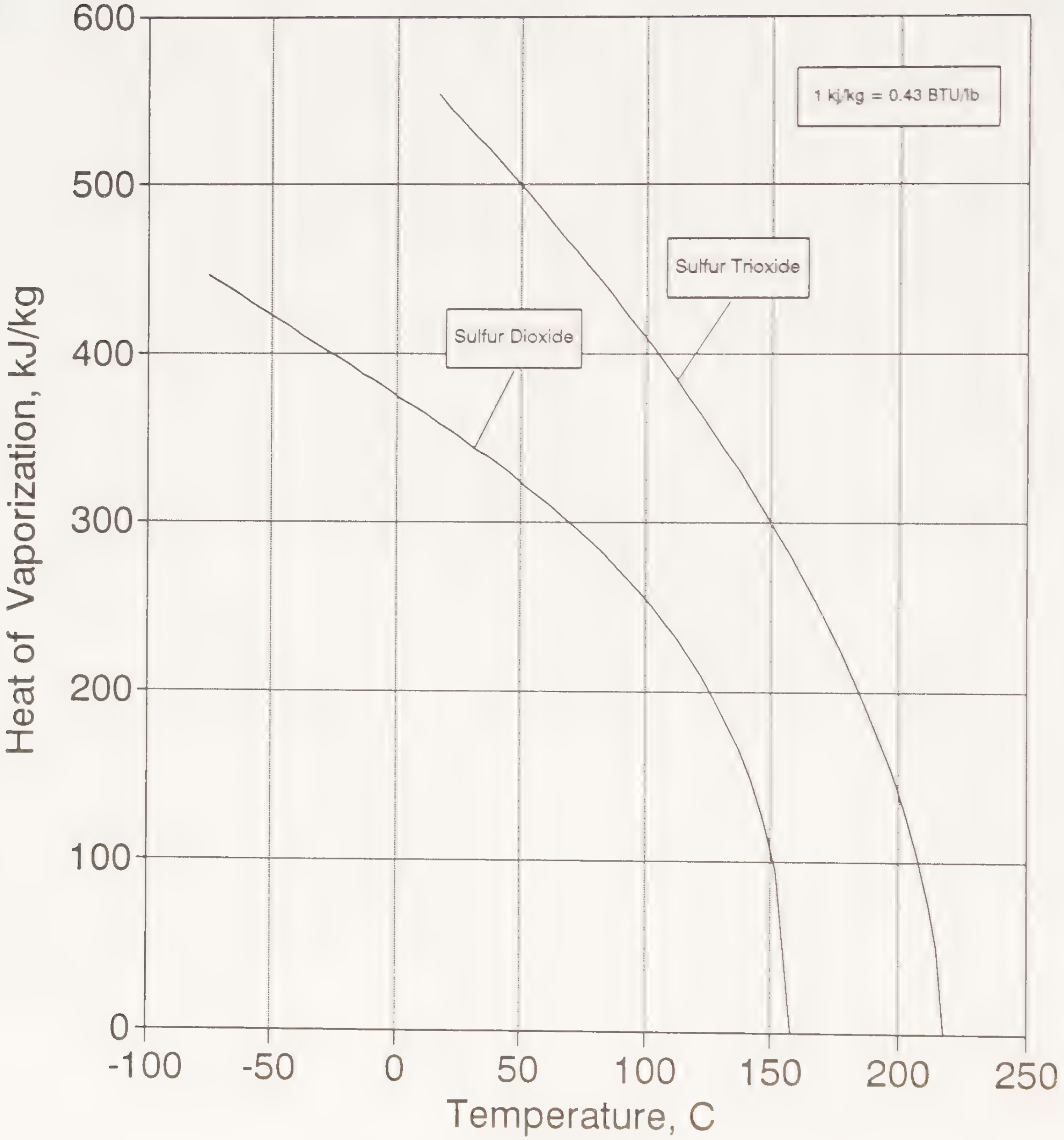

Figure 9-2 Heat of Vaporization

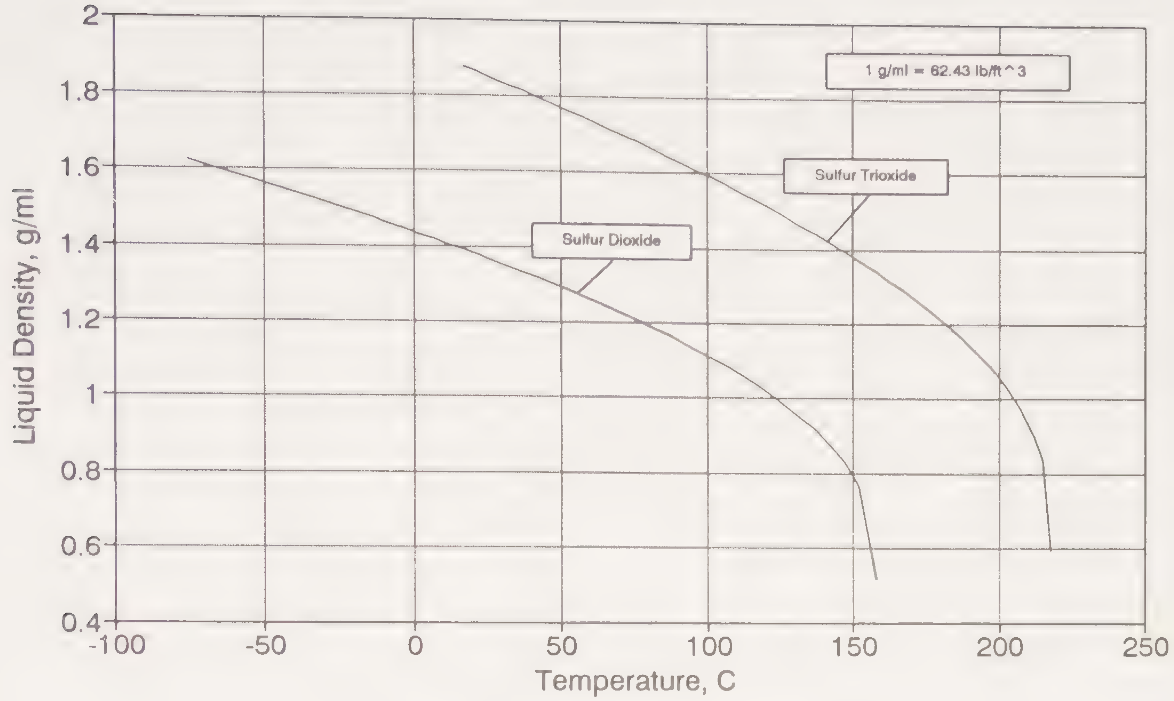

Figure 9-3 Liquid Density

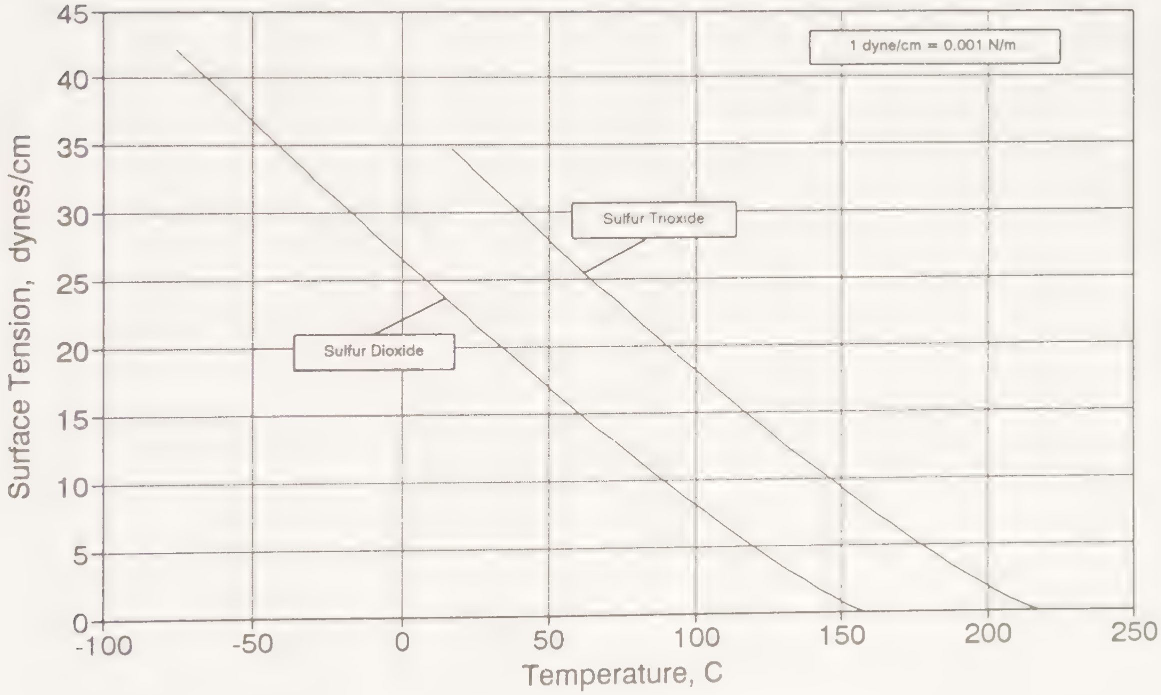

Figure 9-4 Surface Tension

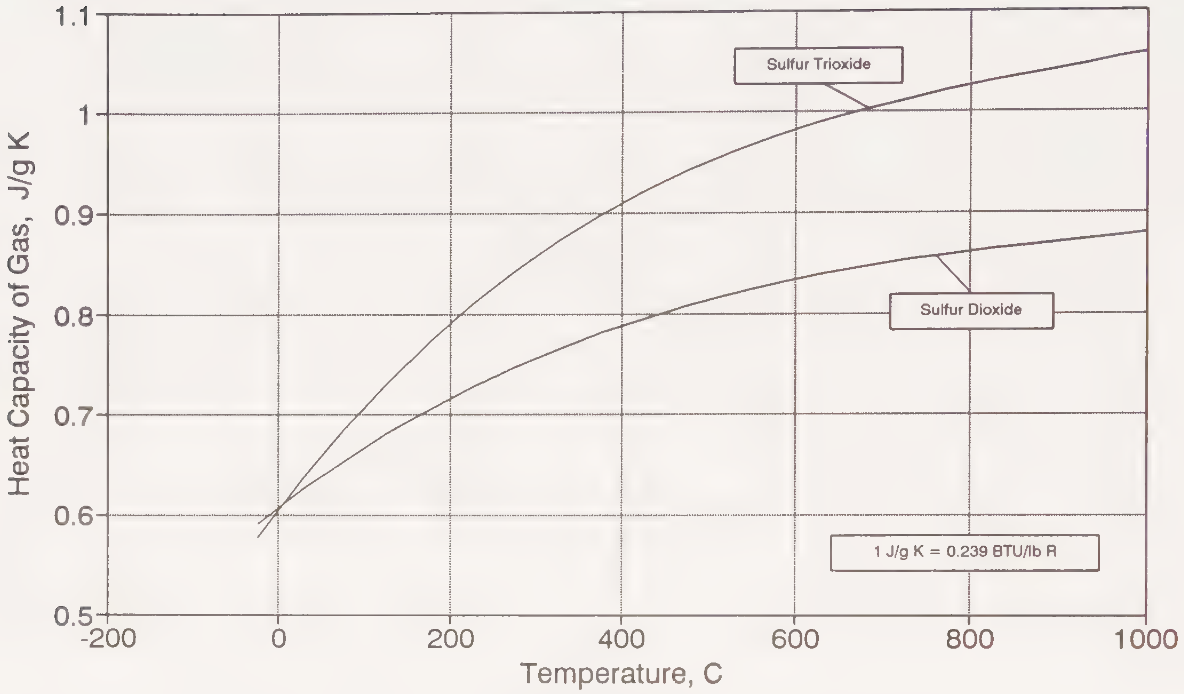

Figure 9-5 Heat Capacity of Gas

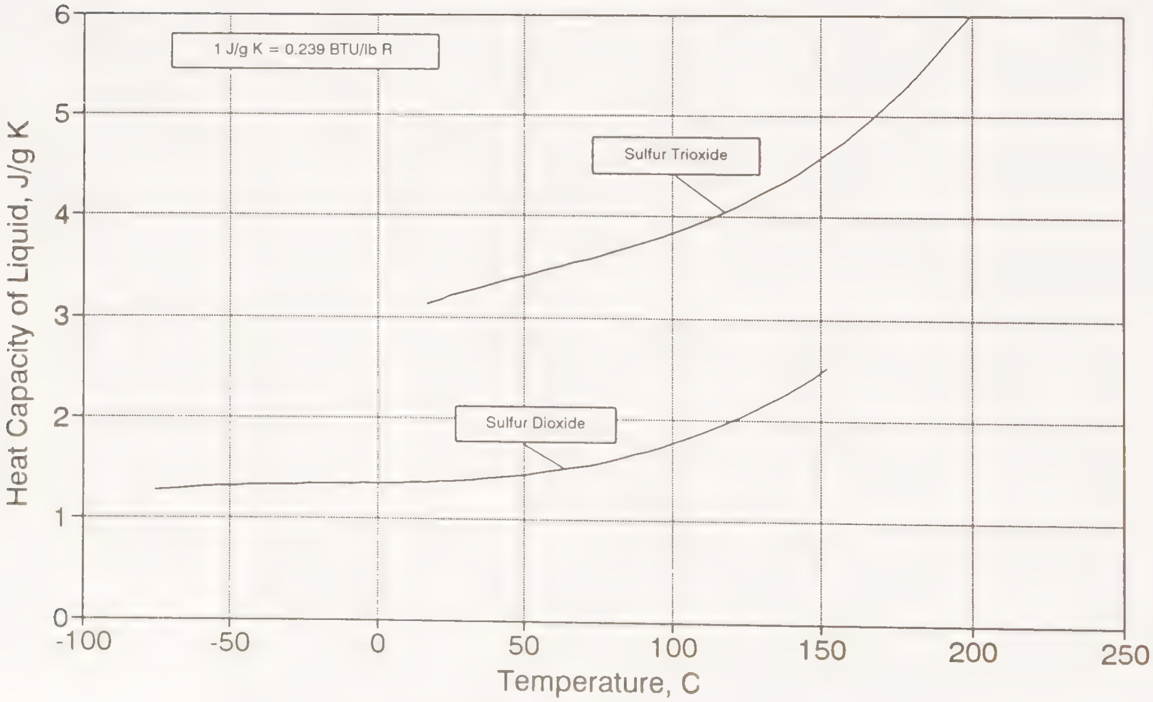

Figure 9-6 Heat Capacity of Liquid

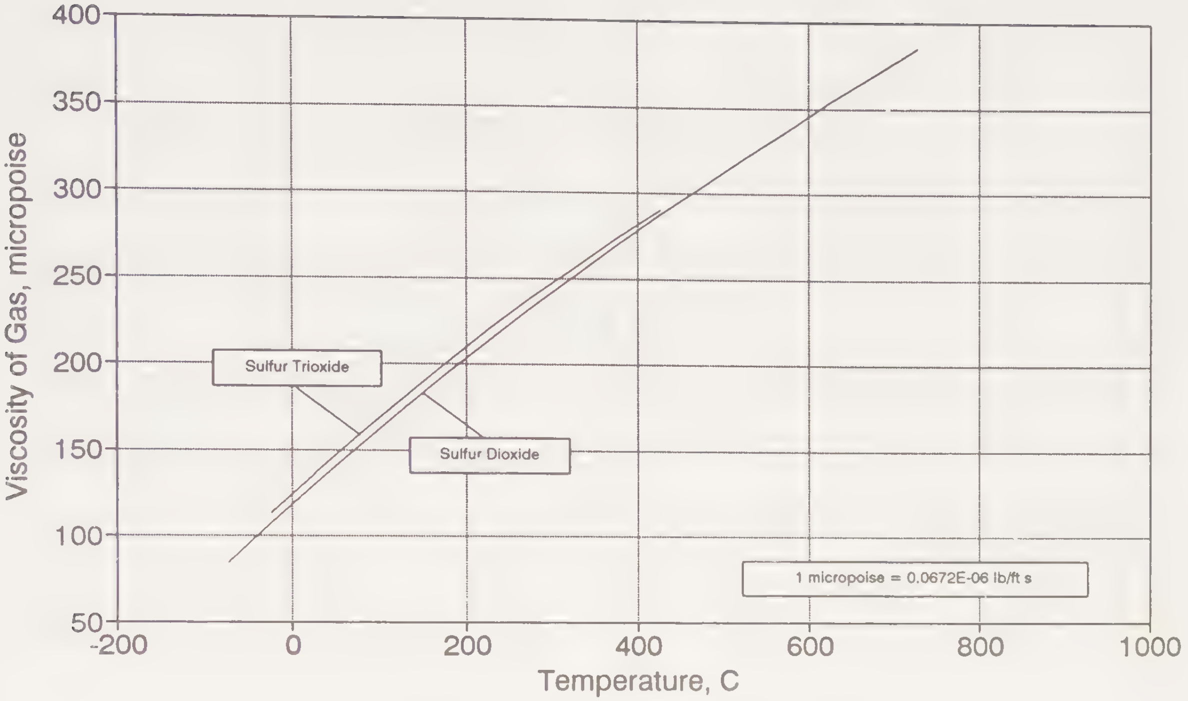

Figure 9-7 Viscosity of Gas

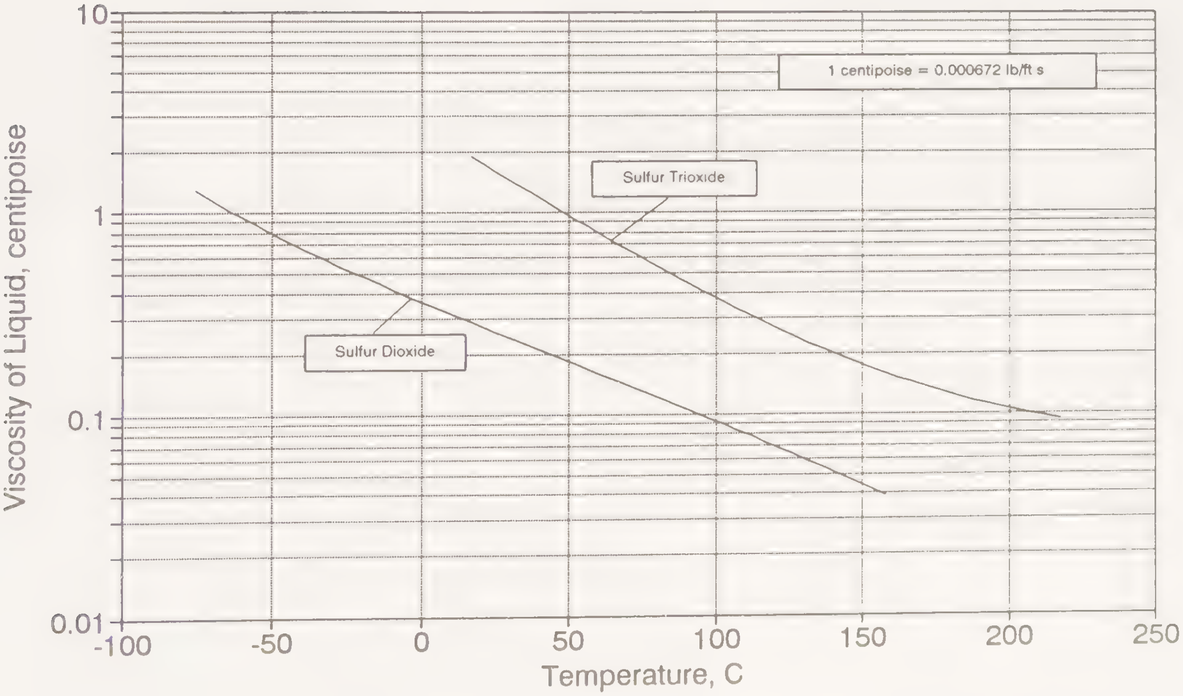

Figure 9-8 Viscosity of Liquid

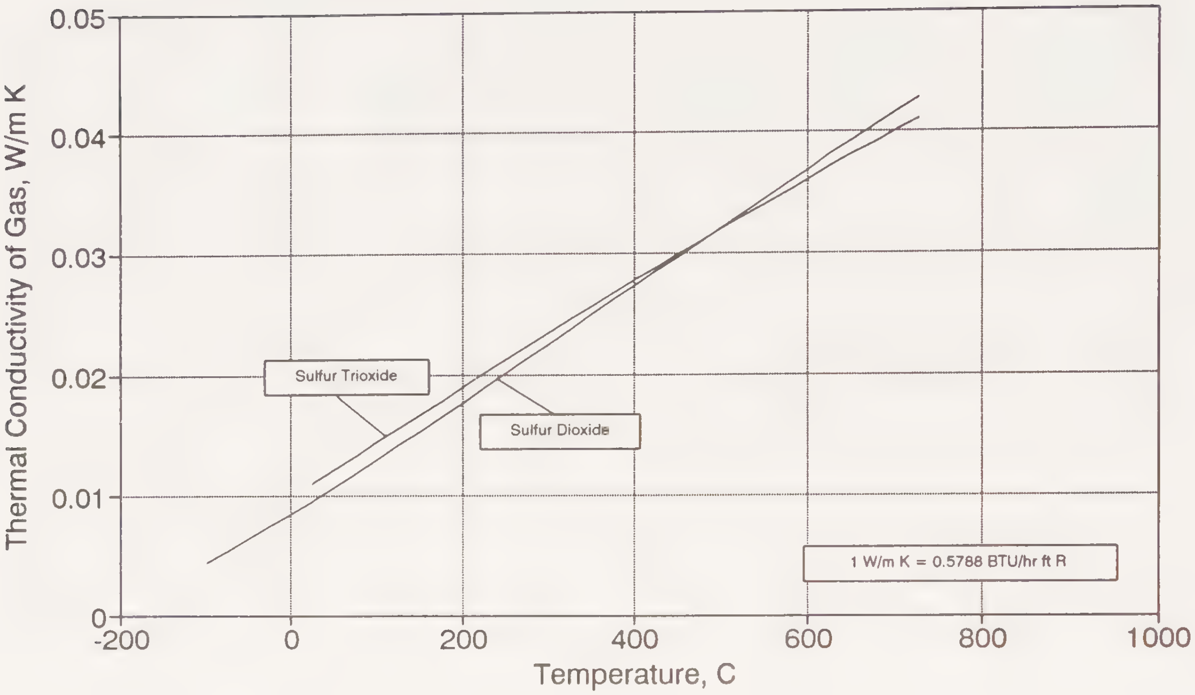

Figure 9-9 Thermal Conductivity of Gas

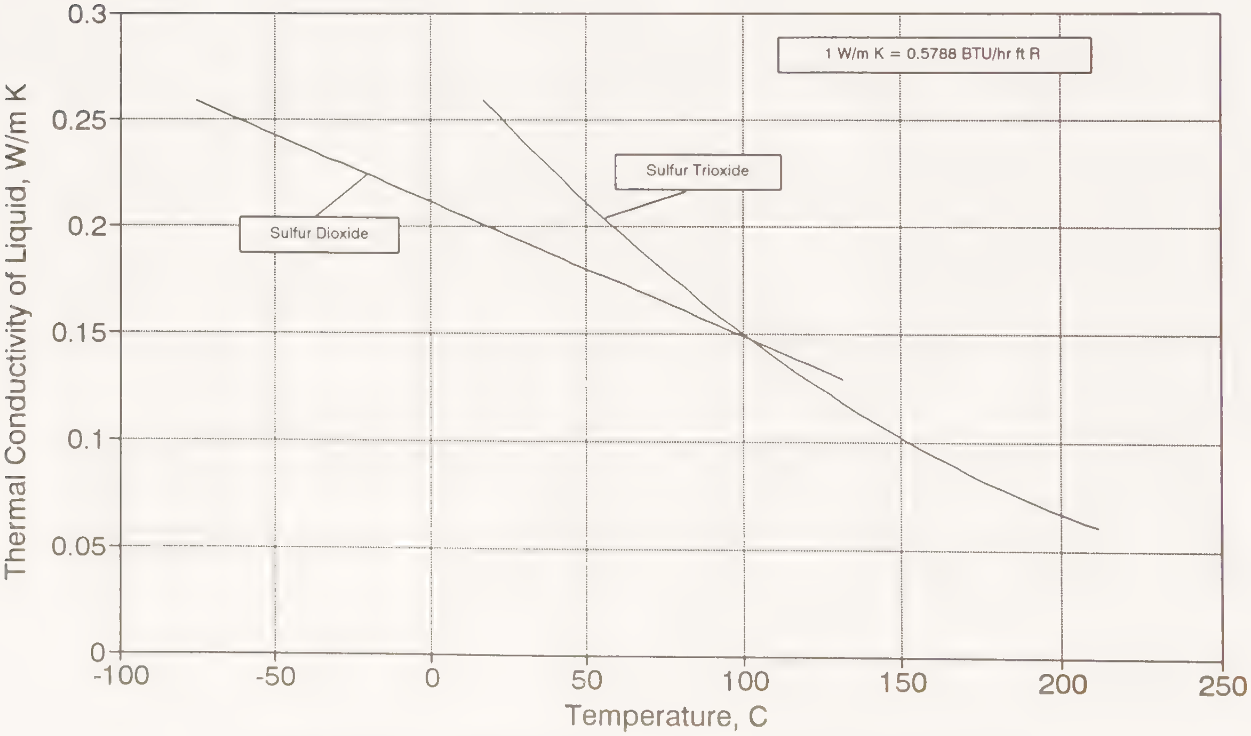

Figure 9-10 Thermal Conductivity of Liquid

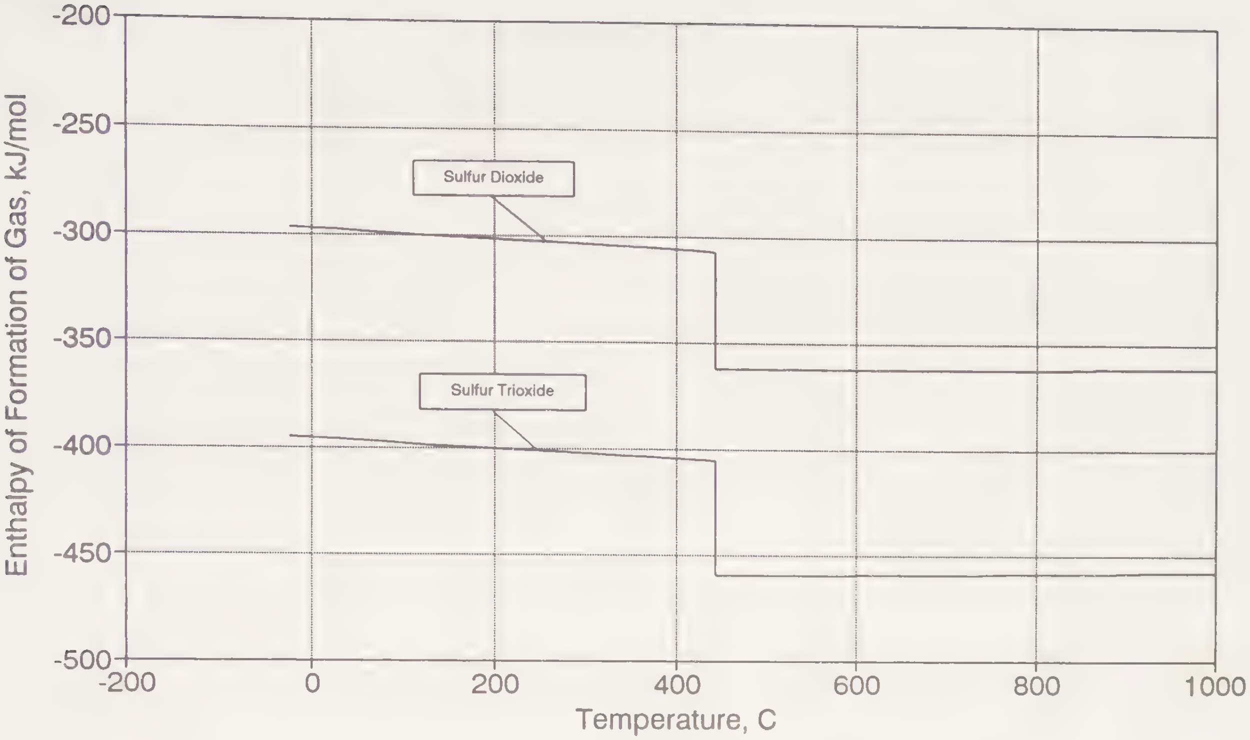

Figure 9-11 Enthalpy of Formation of Gas

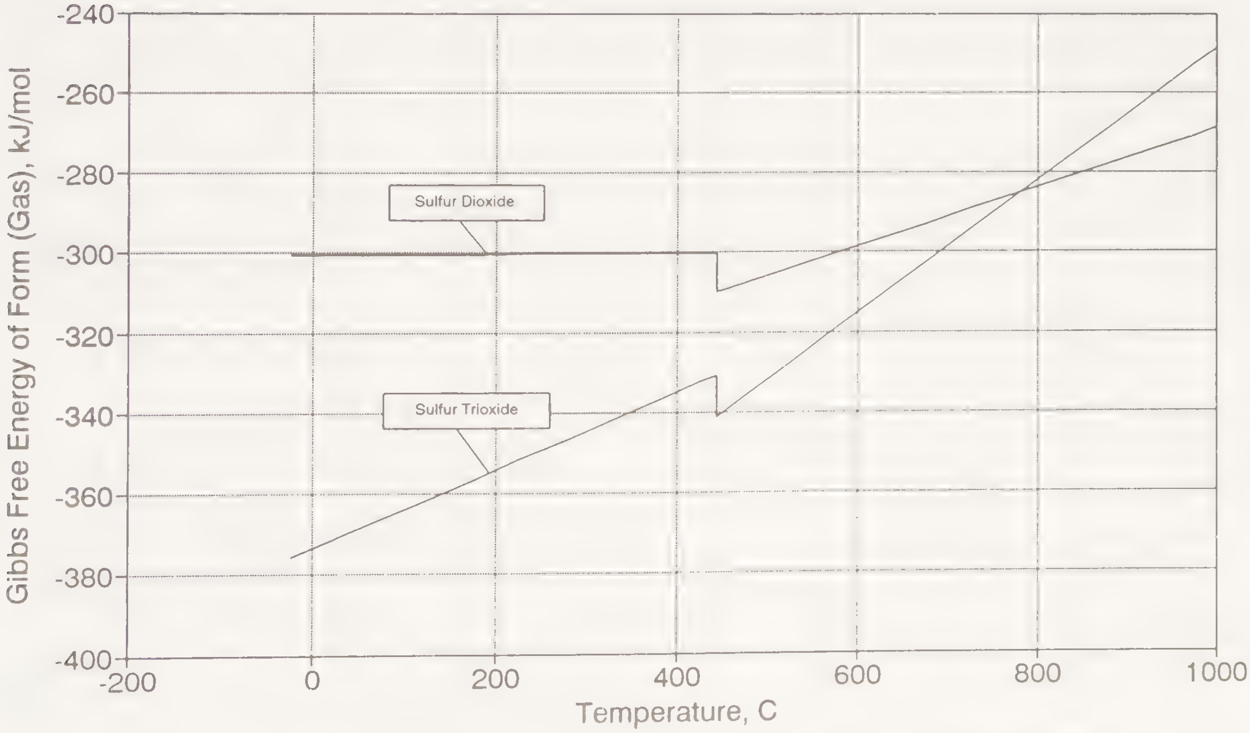

Figure 9-12 Gibbs Free Energy of Formation of Gas

Chapter 10

HYDROGEN AND CARBONYL SULFIDES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 10-1

Property data from the literature (2,3,5-8,13-17,20-24,33,34,36-38,43,139,149-154) are given in Table 10-1. The critical constants (temperature, pressure, volume and compressibility factor) have been determined experimentally. Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) was consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 10-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 10-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 10-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 10-4

Results from the DIPPR project (5) were selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 10% or less in most cases.

HEAT CAPACITY - Figures 10-5 and 10-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5a). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The curve for hydrogen sulfide was extended by using a shape similar to that for carbonyl sulfide. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 10-7 and 10-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in agreement with data. Errors are about 10% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in rough agreement with errors being about 25-50% or less.

THERMAL CONDUCTIVITY - Figures 10-9 and 10-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 5% or less except for hydrogen sulfide (possible 25%).

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less except for hydrogen sulfide (possible 25%).

ENTHALPY OF FORMATION - Figure 10-11

Results from the DIPPR project (5) and JANAF tables (37,110) were selected for enthalpy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 10-12

Results from the DIPPR project (5) and JANAF tables (37,110) were selected for Gibb's free energy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-12). Results from the correlation are in favorable agreement with data.

Table 10-1 Physical Properties

1. Name	Carbonyl Sulfide	Hydrogen Sulfide
2. Formula	COS	H2S
3. Molecular Weight, g/mol	60.076	80.064
4. Critical Temperature, K	378.80	373.53
5. Critical Pressure, bar	63.49	89.629
6. Critical Volume, ml/mol	135.10	98.49
7. Critical Compressibility Factor	0.272	0.284
8. Acentric Factor	0.0970	0.0827
9. Melting Point, K	134.35	187.68
10. Boiling Point @ 1 atm, K	223.00	212.80
11. Heat of Vaporization @ BP, kJ/kg	309.81	554.19
12. Density of Liquid @ 25 C, g/ml	1.005	0.777
13. Surface Tension @ 25 C, dynes/cm	7.87	9.13
14. Heat Capacity of Gas @ 25 C, J/g K	0.692	1.003
15. Heat Capacity of Liquid @ 25 C, J/g K	1.392	2.202
16. Viscosity of Gas @ 25 C, micropoise	128.0	126.0
17. Viscosity of Liquid @ 25 C, centipoise	------	------
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0139	0.0145
19. Thermal Conductivity of Liquid @ 25 C, W/m K	------	0.131
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-138.41	-20.42
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	-165.67	-33.32
22. Flash Point, K	------	------
23. Autoignition Temperature, K	------	533.15
24. Lower Explosion Limit in Air, vol %	12.0	4.3
25. Upper Explosion Limit in Air, vol %	29.0	45.0
26. Solubility in Water @ 25 C, ppm(wt)	1,150	3,173

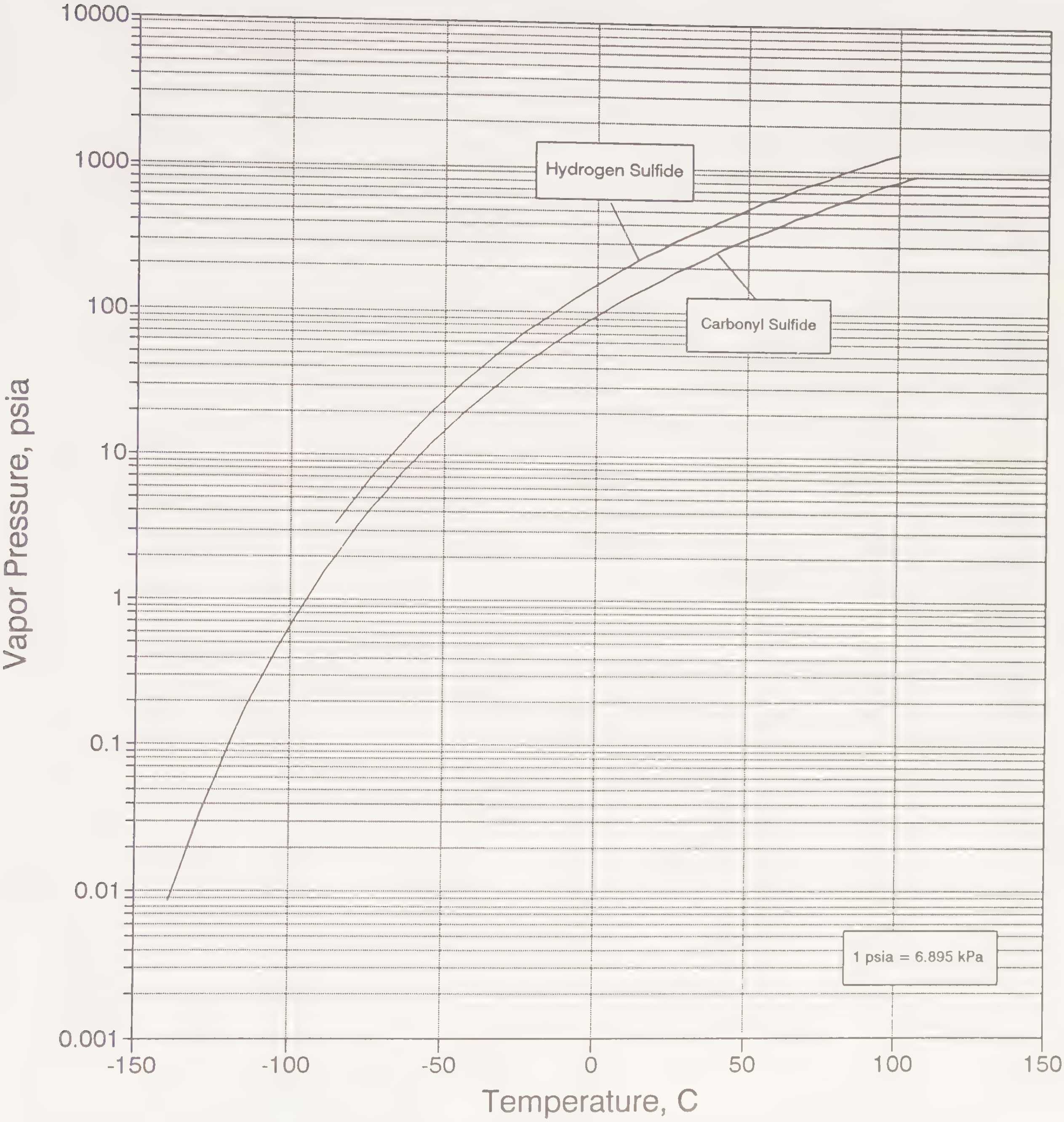

Figure 10-1 Vapor Pressure

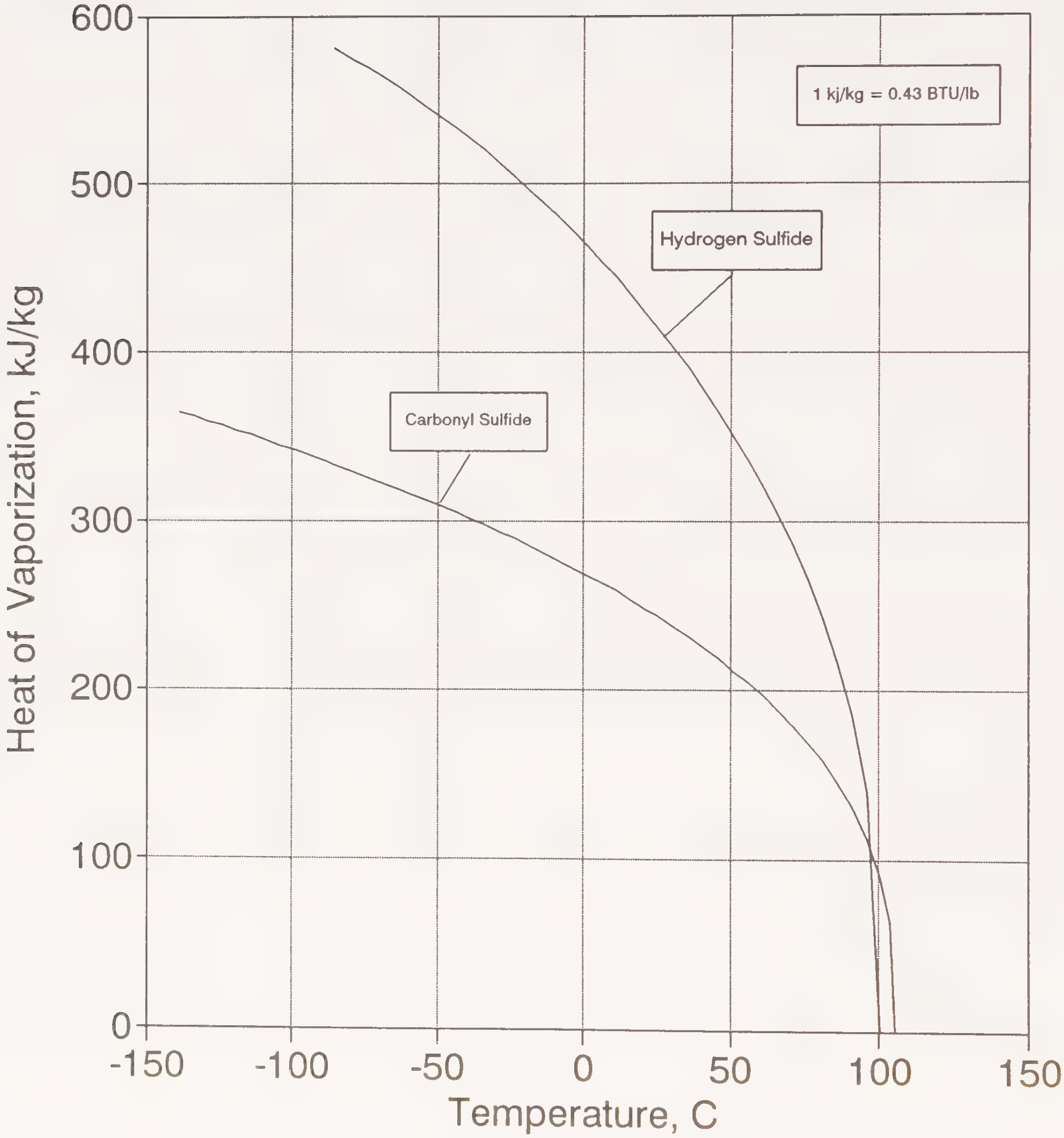

Figure 10-2 Heat of Vaporization

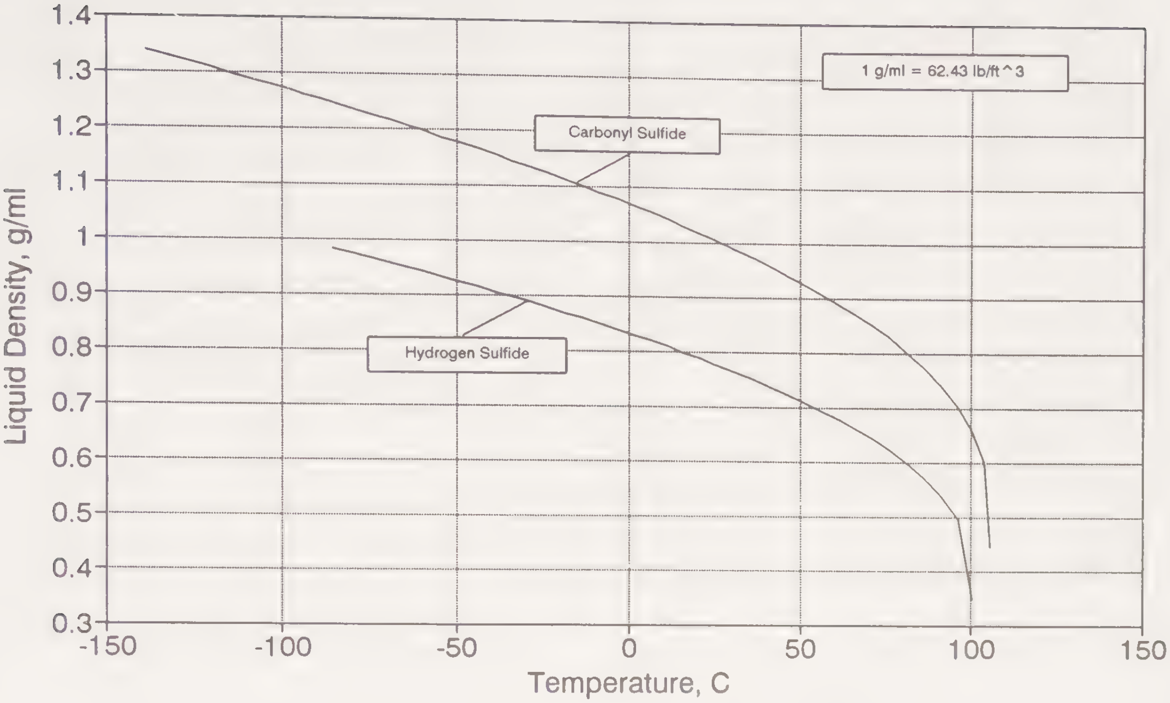

Figure 10-3 Liquid Density

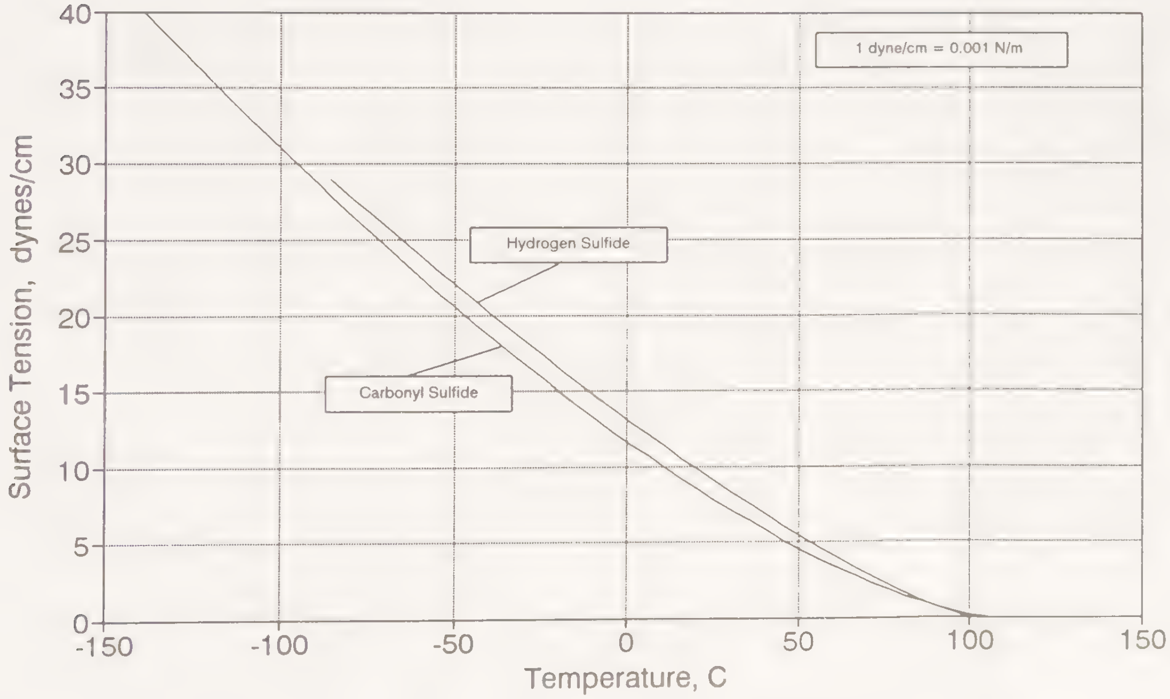

Figure 10-4 Surface Tension

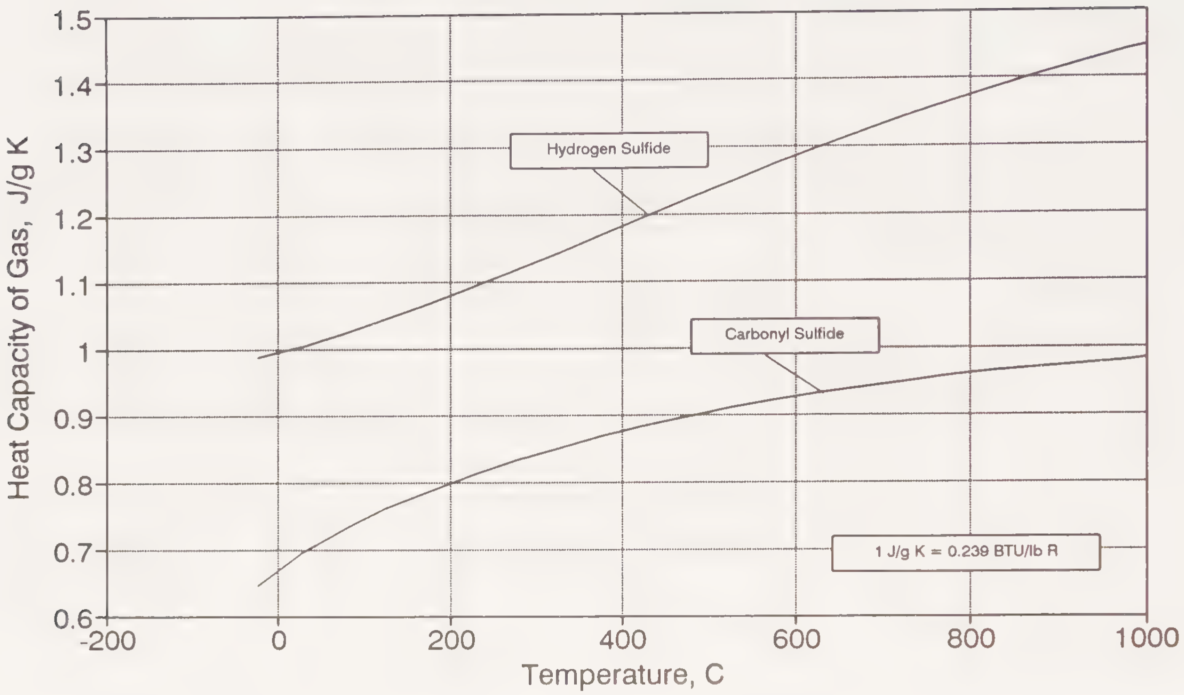

Figure 10-5 Heat Capacity of Gas

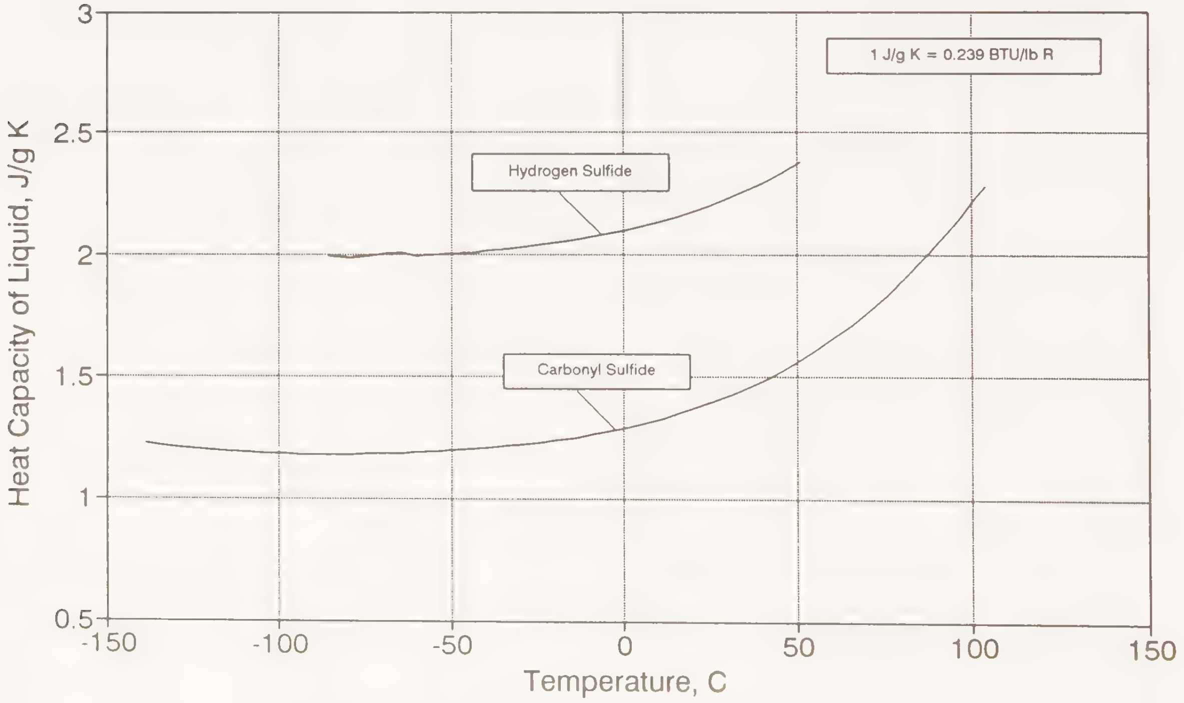

Figure 10-6 Heat Capacity of Liquid

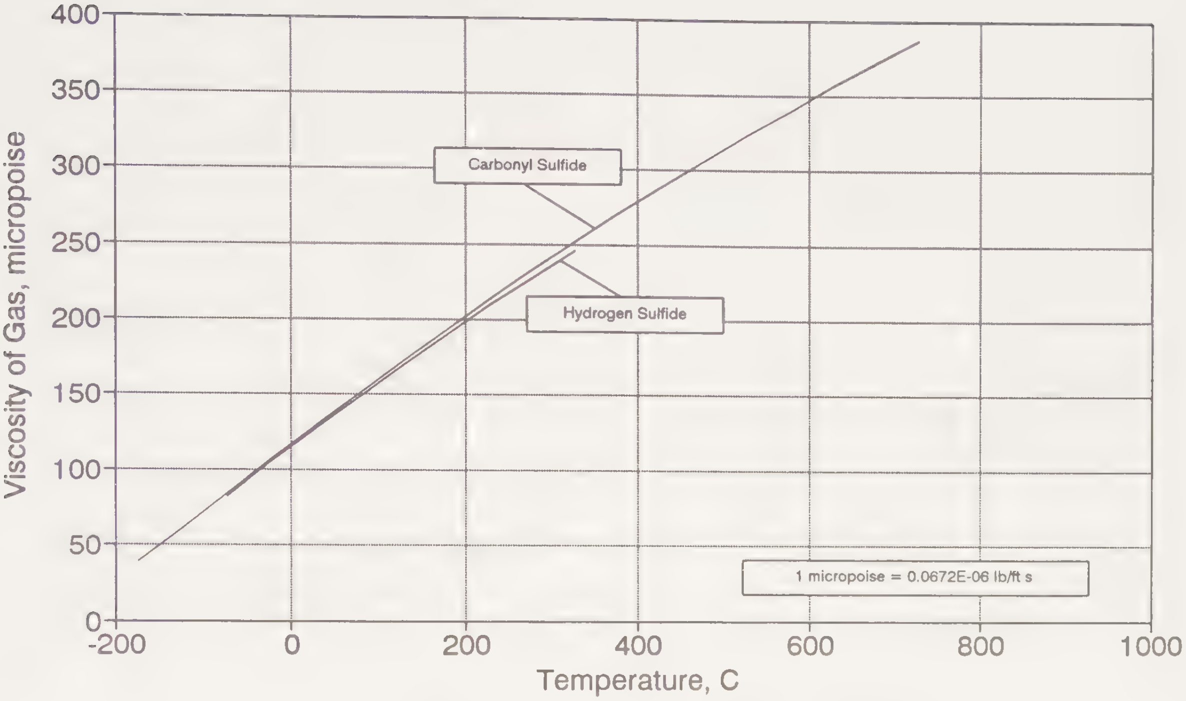

Figure 10-7 Viscosity of Gas

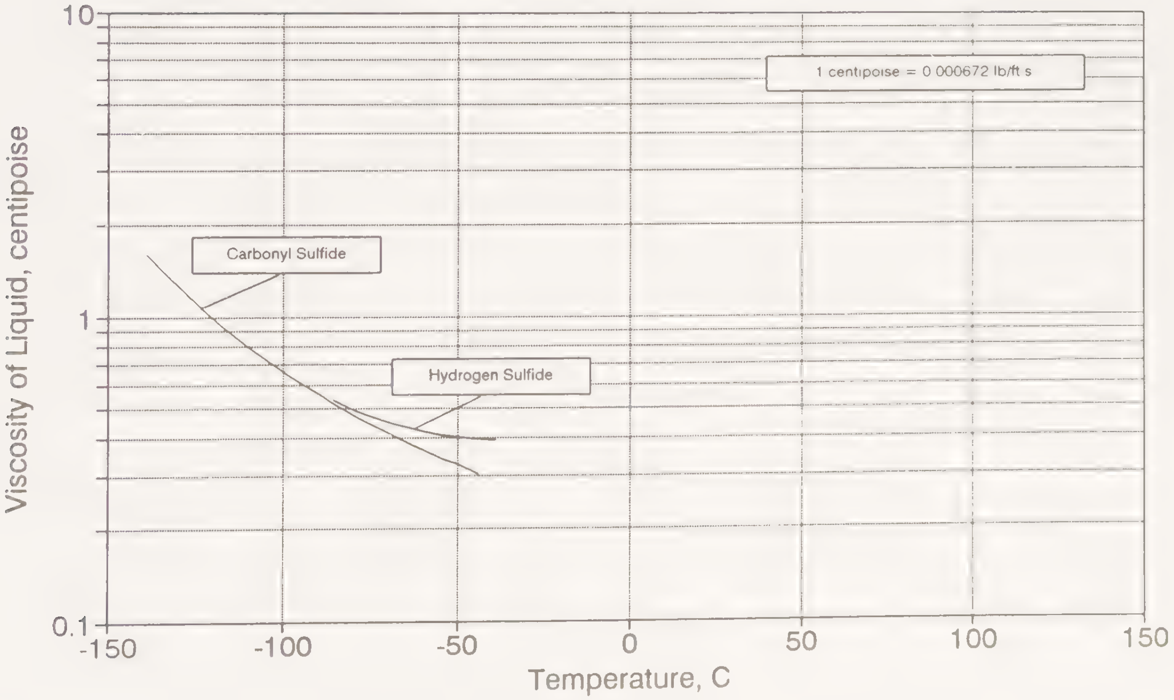

Figure 10-8 Viscosity of Liquid

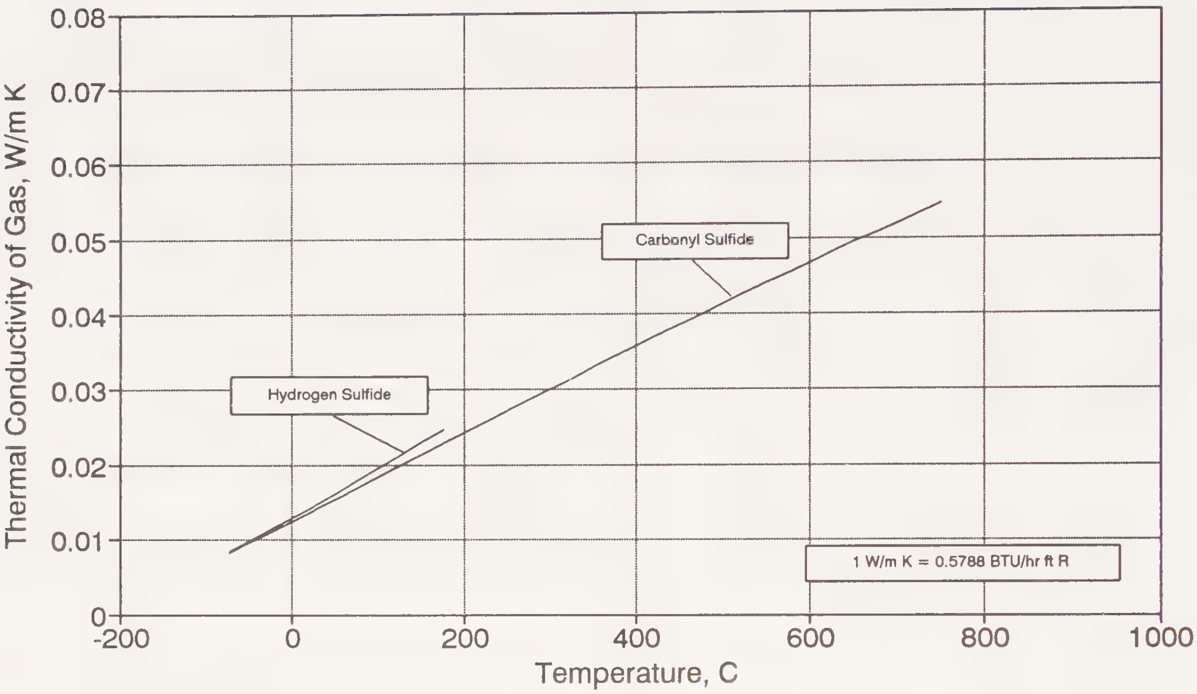

Figure 10-9 Thermal Conductivity of Gas

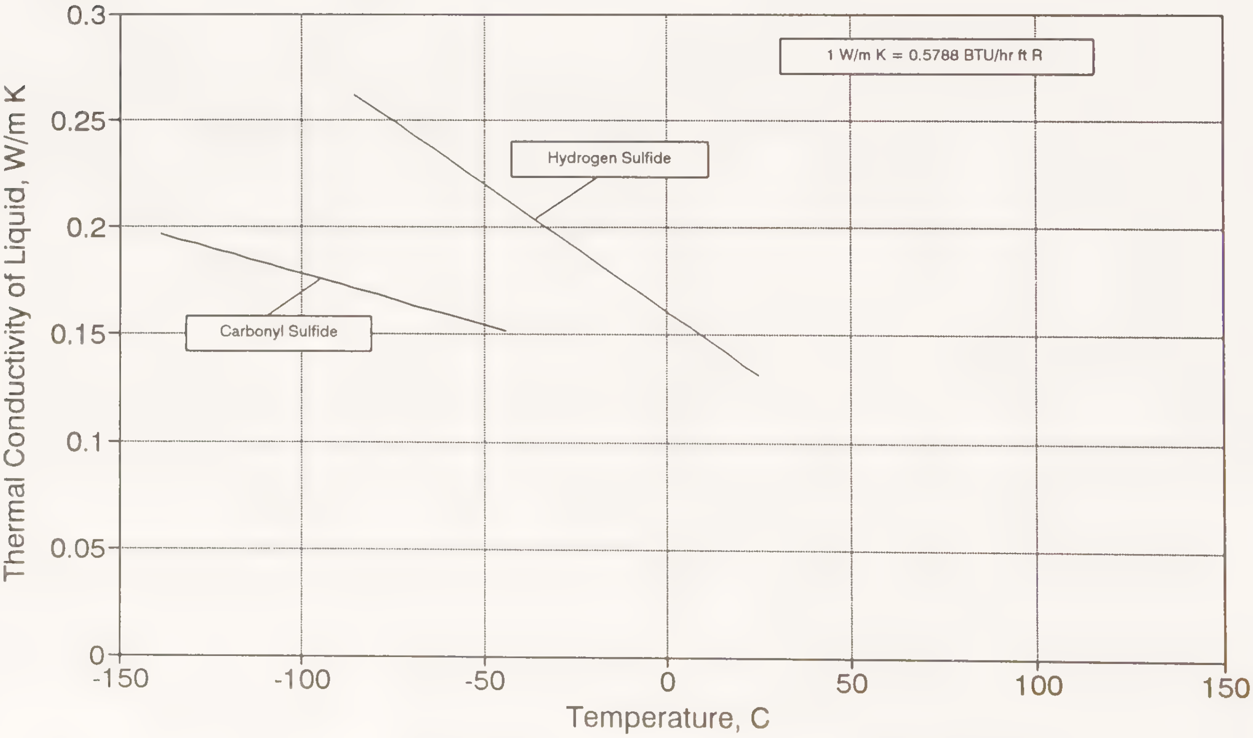

Figure 10-10 Thermal Conductivity of Liquid

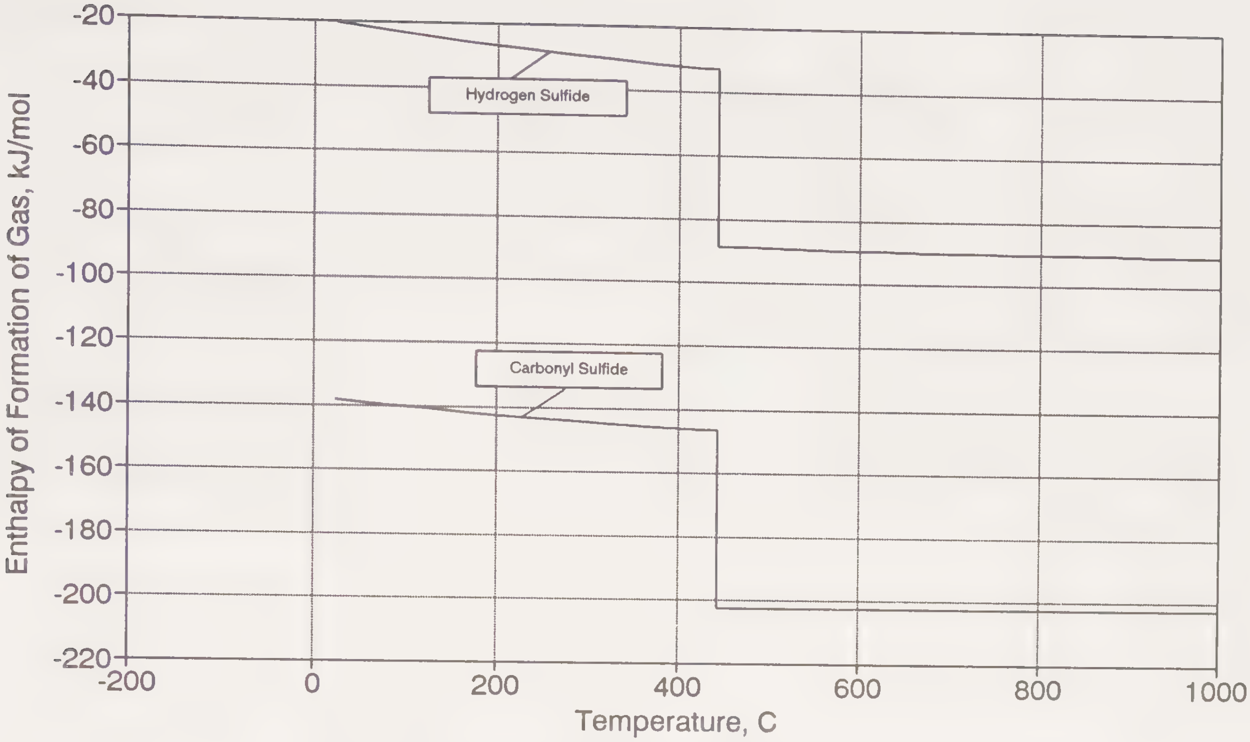

Figure 10-11 Enthalpy of Formation of Gas

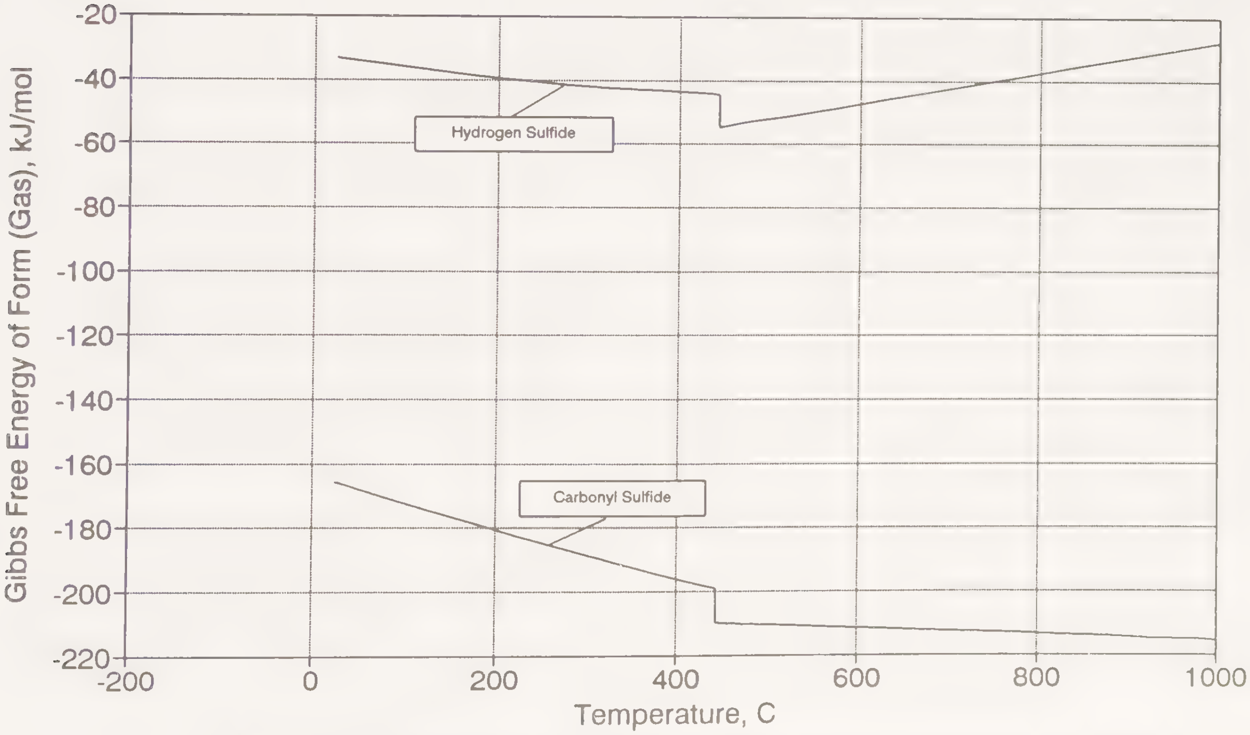

Figure 10-12 Gibbs Free Energy of Formation of Gas

Chapter 11

HYDROGEN HALIDES

Robert W. Gallant, Carl L. Yaws and Xiaoyan Lin

PHYSICAL PROPERTIES - Table 11-1

Property data from the literature (1-55,110,134,148,190,191) are given in Table 11-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation, lower explosion limit in air and solubility in water are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and data compilations by Yaws and co-workers (31) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 11-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 11-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. Equation (1-2) was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3%.

LIQUID DENSITY - Figure 11-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. Equation (1-3) was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 11-4

Results from the DIPPR project (5) were selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by Equation (1-4). Accuracy is good with errors being about 25% or less in most cases.

HEAT CAPACITY - Figures 11-5 and 11-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5b). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (31) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in fair agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 11-7 and 11-8

Results from the data compilation of Yaws and co-workers (31) were selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7a). Results are in fair agreement with data. Errors are about 25% or less in most cases.

Results from the data compilation of Yaws and co-workers (31) were selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8a). Correlation results and data are in agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 11-9 and 11-10

Results from the data compilation of Yaws and co-workers (31) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using a series expansion in temperature. Reliability of results is rough with possible errors of 25%.

Results from the data compilation of Yaws and co-workers (31) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10a). Reliability of results is rough with possible errors of 10%.

ENTHALPY OF FORMATION - Figure 11-11

The data compilation of Yaws and co-workers (31) was selected for enthalpy of formation of ideal gas. The vertical shifts in the curve for hydrogen iodide and hydrogen bromide reflects the change in the standard reference state of the elements. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 11-12

The data compilation of Yaws and co-workers (31) was selected for Gibb's free energy of formation of ideal gas. The vertical shifts in the curve for hydrogen iodide and hydrogen bromide reflects the change in the standard reference state of the elements. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Results from the correlation are in favorable agreement with data.

Table 11-1 Physical Properties

1. Name	Hydrogen Chloride	Hydrogen Bromide	Hydrogen Iodide	Hydrogen Fluoride
2. Formula	HCl	HBr	HI	HF
3. Molecular Weight, g/mol	36.461	80.912	127.912	20.006
4. Critical Temperature, K	324.65	363.15	423.85	461.15
5. Critical Pressure, bar	83.087	85.518	83.100	64.848
6. Critical Volume, ml/mol	81.02	100.26	121.94	69.00
7. Critical Compressibility Factor	0.249	0.284	0.288	0.117
8. Acentric Factor	0.1322	0.0693	0.0381	0.3826
9. Melting Point, K	158.97	186.34	222.38	189.79
10. Boiling Point @ 1 atm, K	188.15	206.45	237.55	292.67
11. Heat of Vaporization @ BP, kJ/kg	444.61	223.22	156.50	334.72
12. Density of Liquid @ 25 C, g/ml	0.796	1.728	2.520	0.941
13. Surface Tension @ 25 C, dynes/cm	3.30	9.20	17.27	8.40
14. Heat Capacity of Gas @ 25 C, J/g K	0.799	0.360	0.228	1.456
15. Heat Capacity of Liquid @ 25 C, J/g K	------	0.95	0.53	3.07
16. Viscosity of Gas @ 25 C, micropoise	144.21	184.48	178.24	110.77
17. Viscosity of Liquid @ 25 C, centipoise	0.07	0.20	0.60	0.20
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0148	0.0097	0.0062	0.0213
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1806	0.1376	0.1661	0.3954
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-92.39	-36.24	26.35	-271.29
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	-95.45	-53.31	1.60	-274.36
22. Flash Point, K	------	------	------	------
23. Autoignition Temperature, K	------	------	------	------
24. Lower Explosion Limit in Air, vol %	------	------	------	------
25. Upper Explosion Limit in Air, vol %	------	------	------	------
26. Solubility in Water @ 25 C,	total	1.93 kg of HBr per kg of water	2.36 kg of HI per kg of water	total

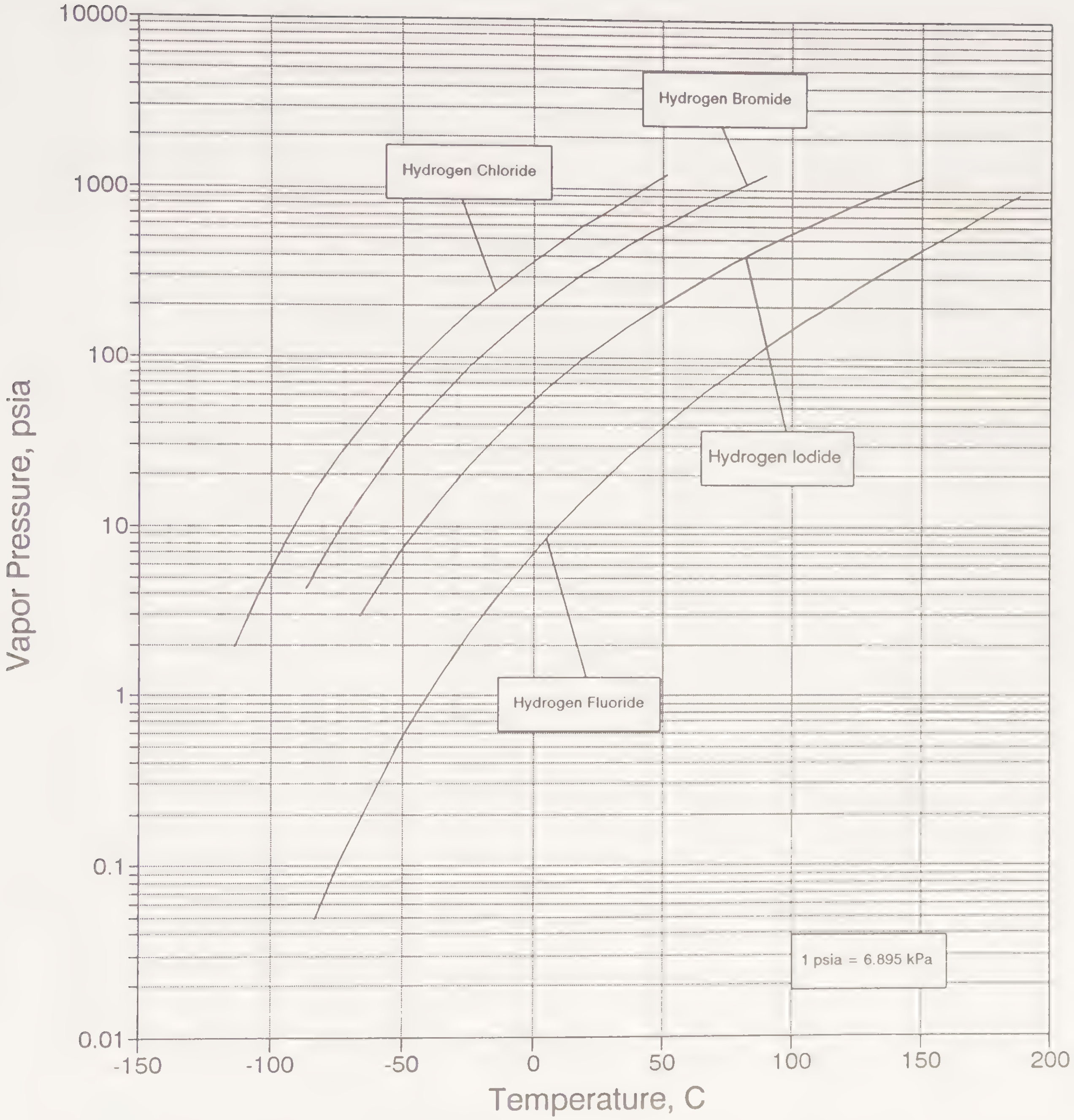

Figure 11-1 Vapor Pressure

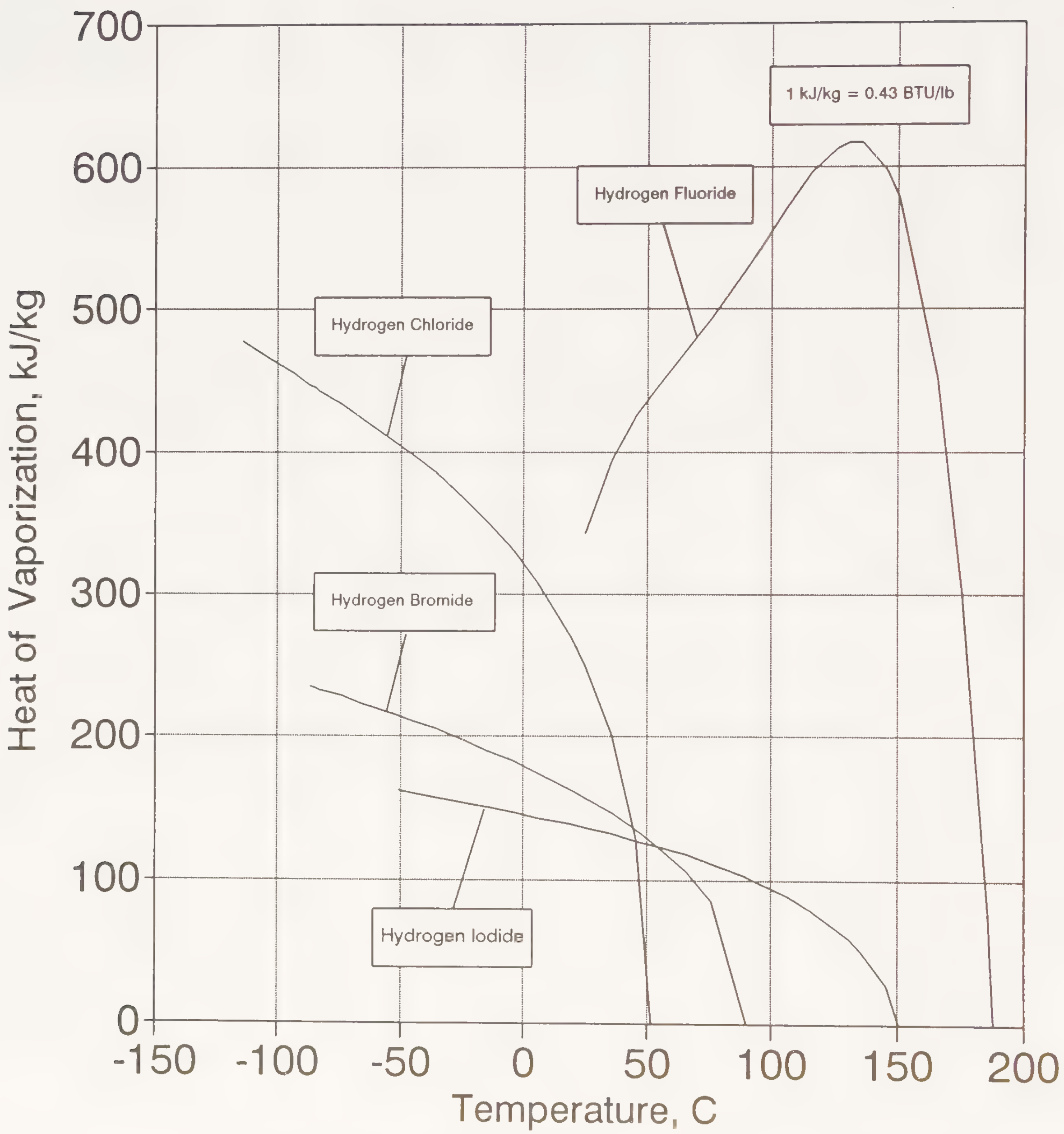

Figure 11-2 Heat of Vaporization

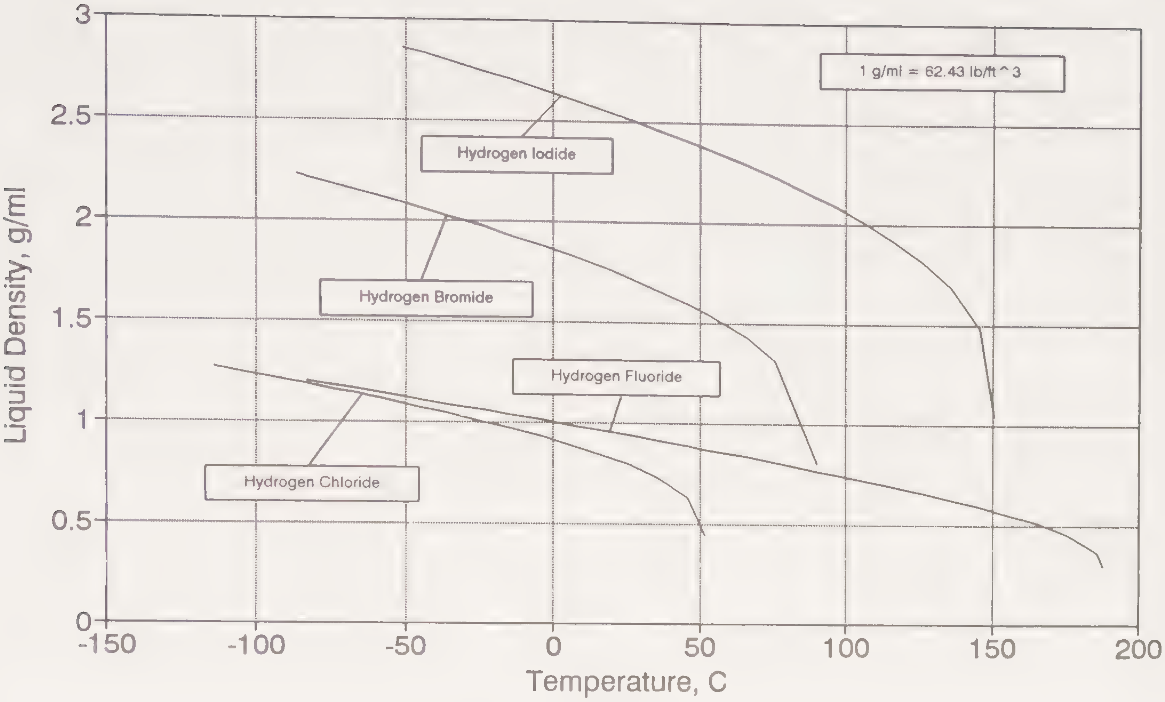

Figure 11-3 Liquid Density

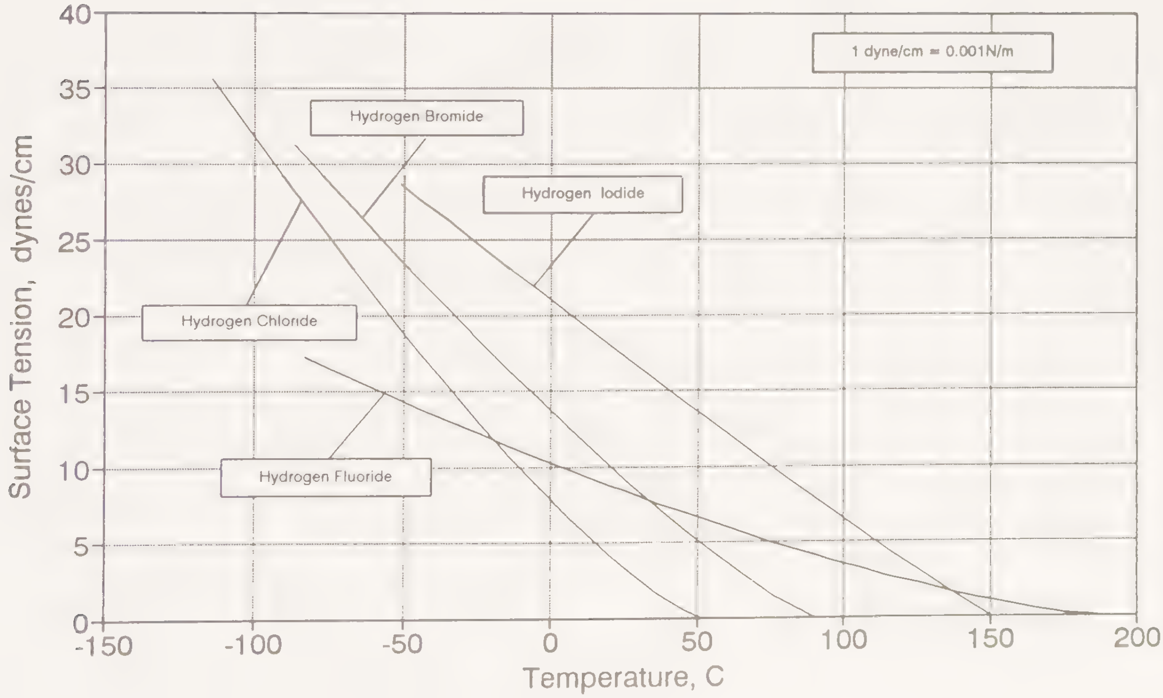

Figure 11-4 Surface Tension

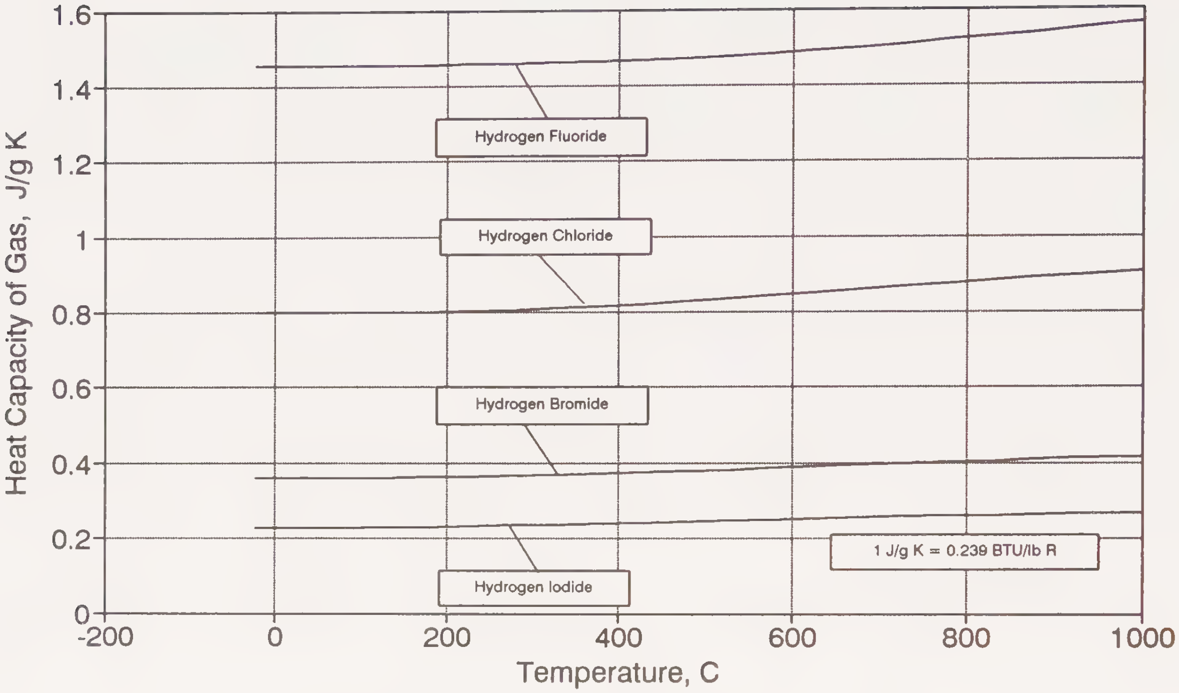

Figure 11-5 Heat Capacity of Gas

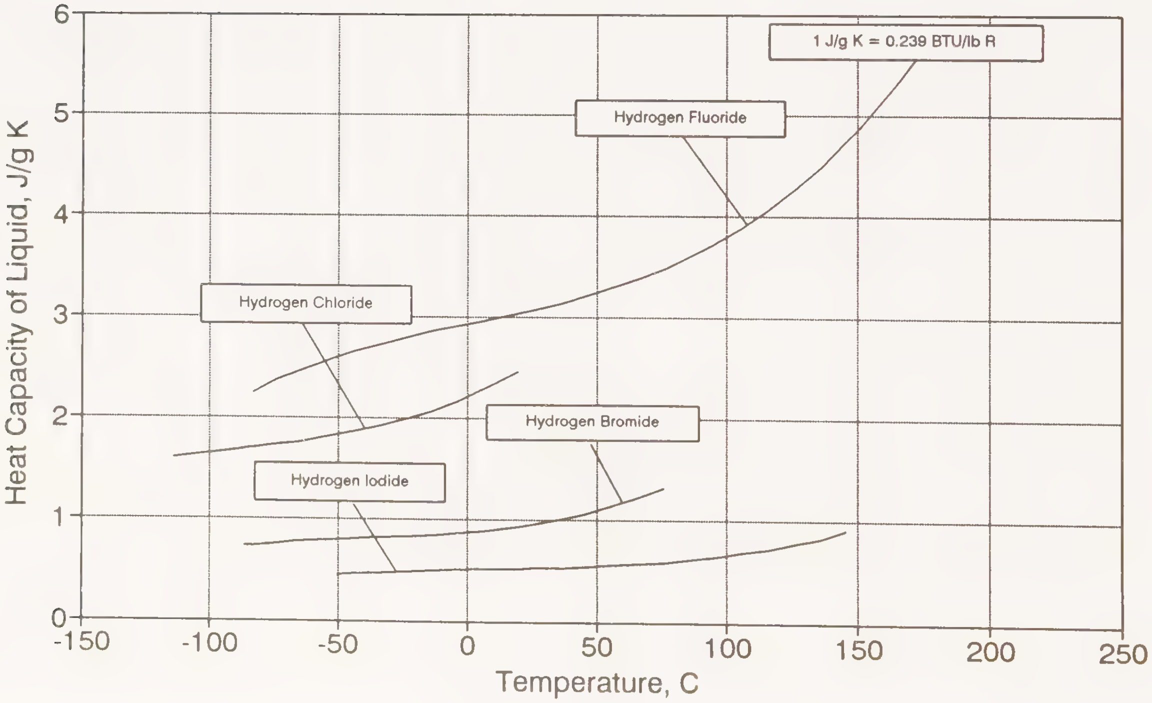

Figure 11-6 Heat Capacity of Liquid

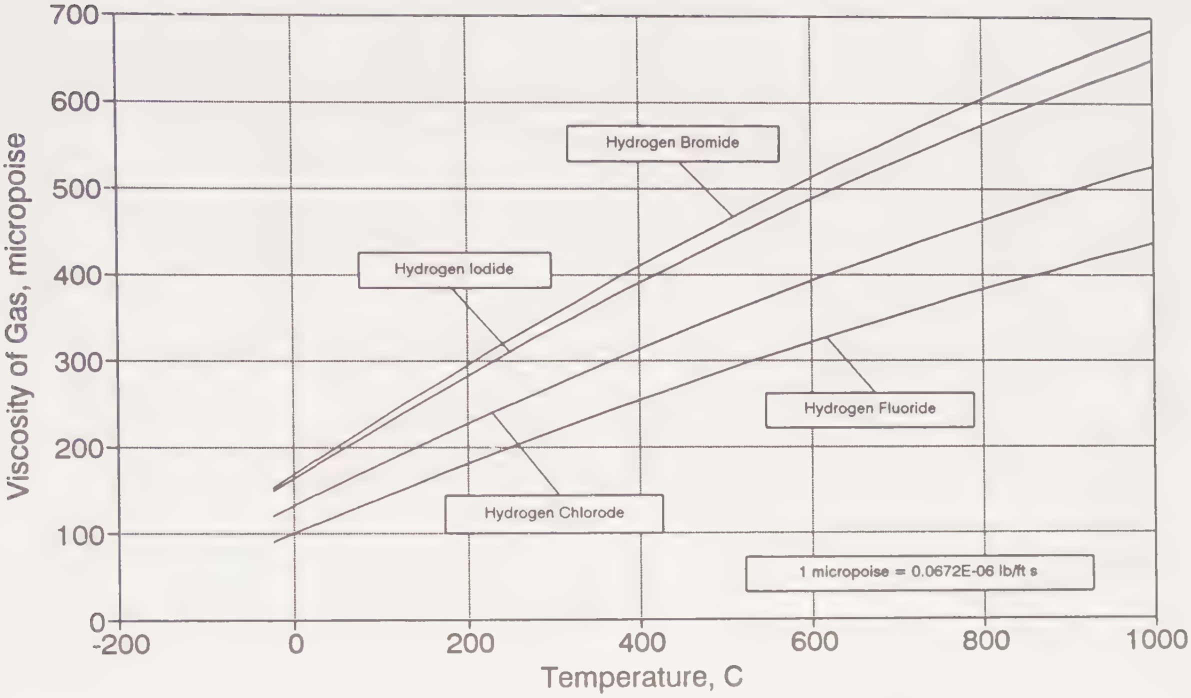

Figure 11-7 Viscosity of Gas

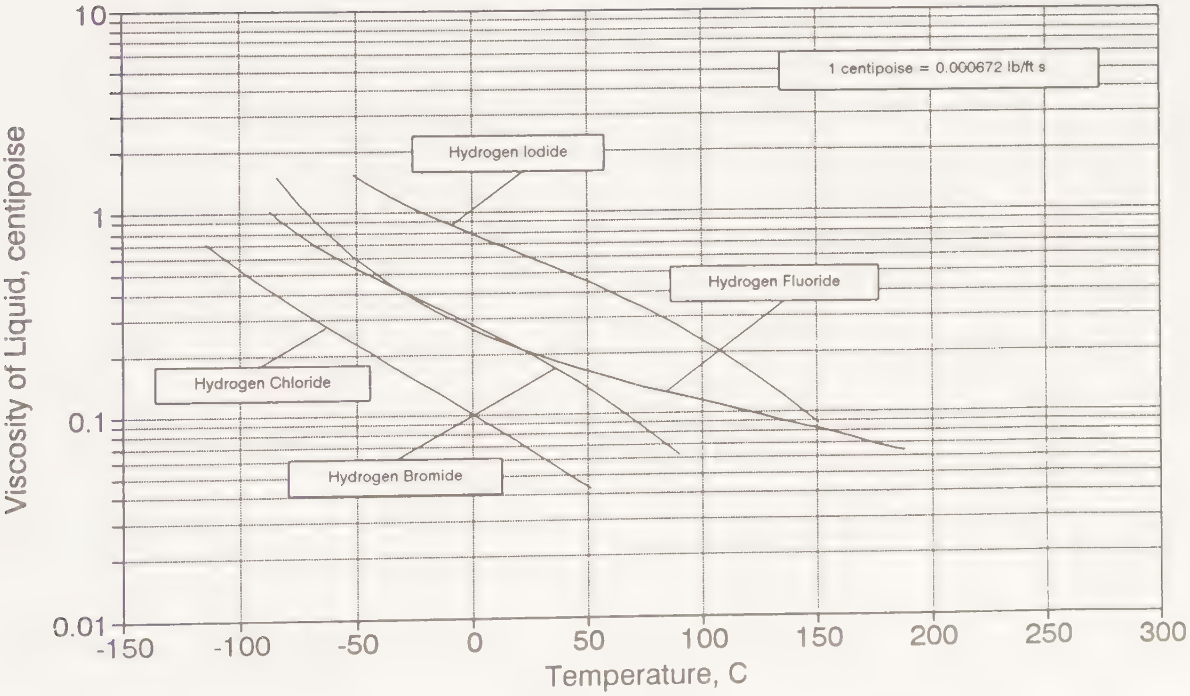

Figure 11-8 Viscosity of Liquid

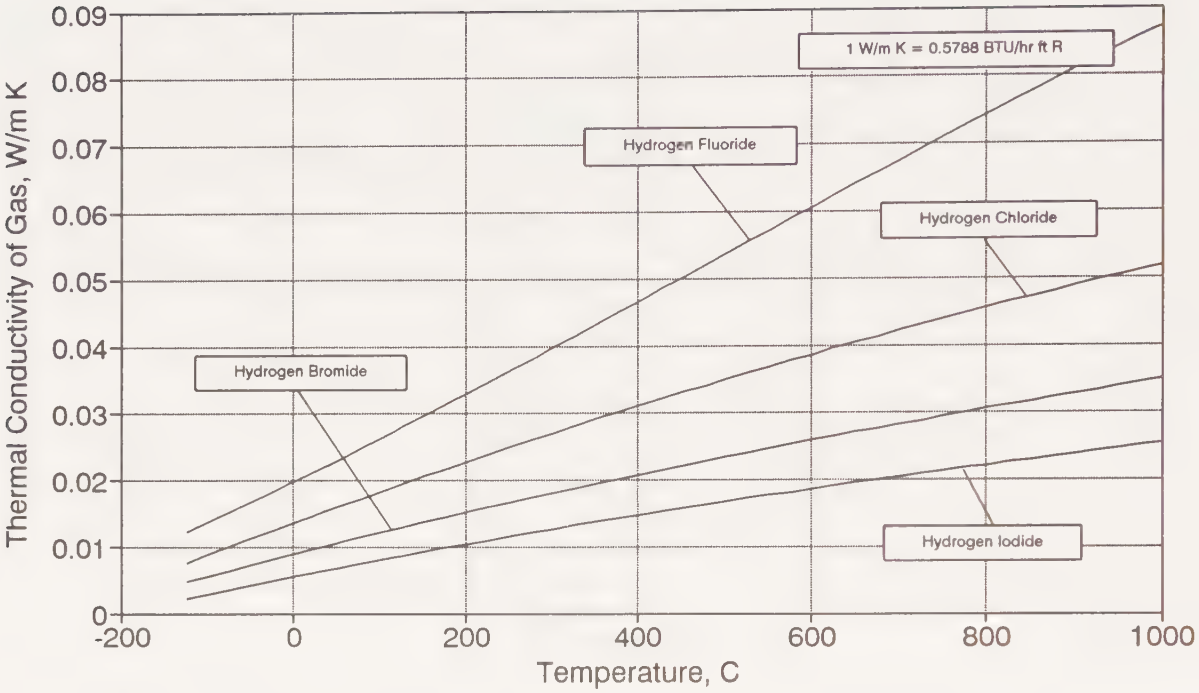

Figure 11-9 Thermal Conductivity of Gas

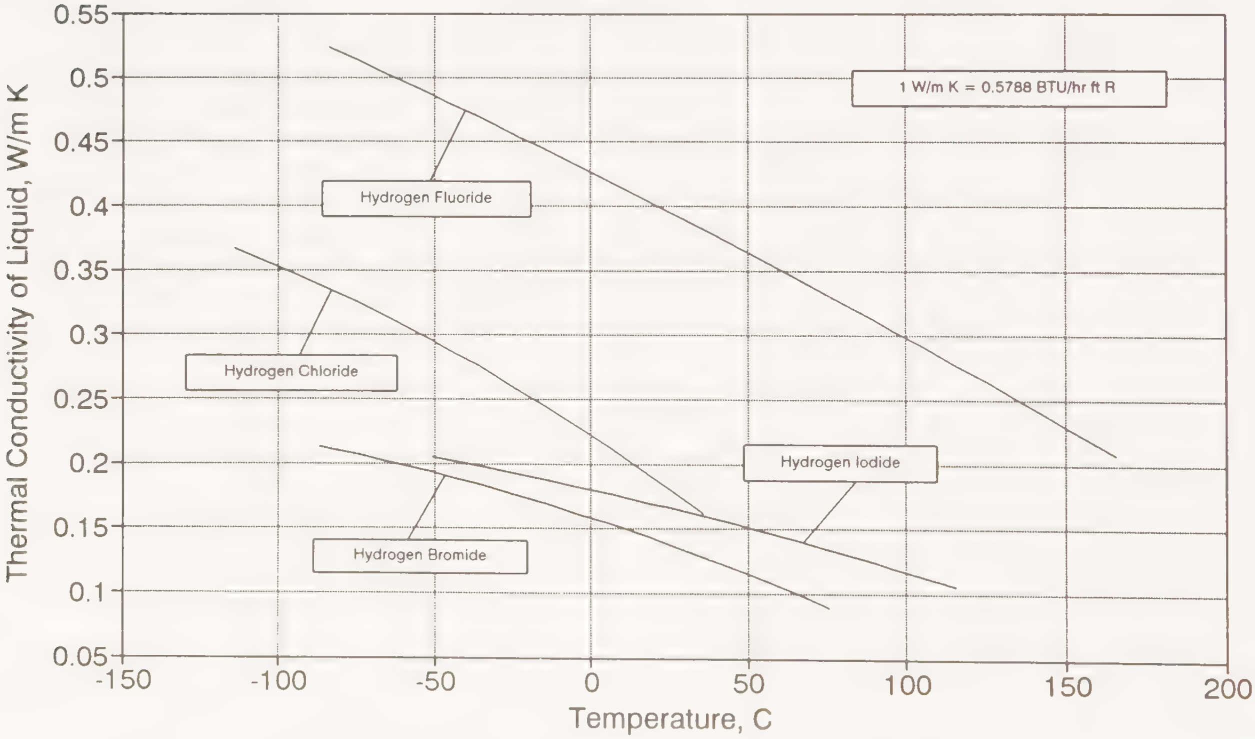

Figure 11-10 Thermal Conductivity of Liquid

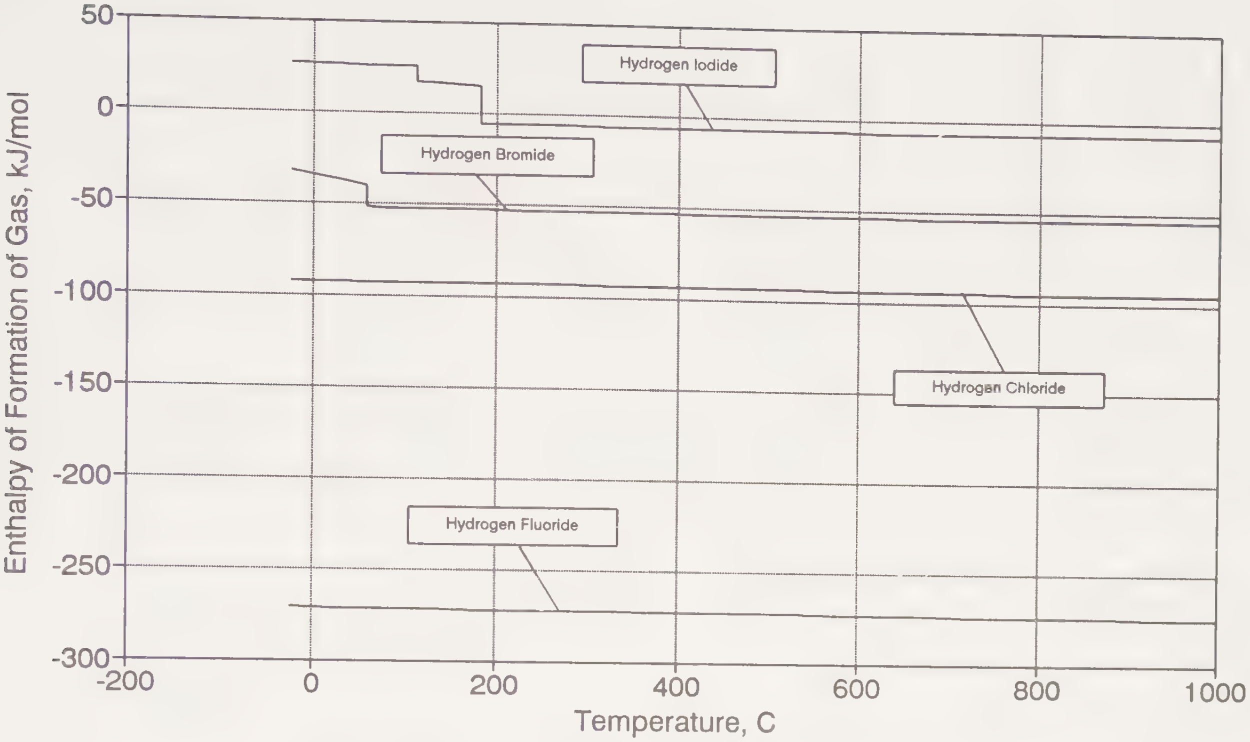

Figure 11-11 Enthalpy of Formation of Gas

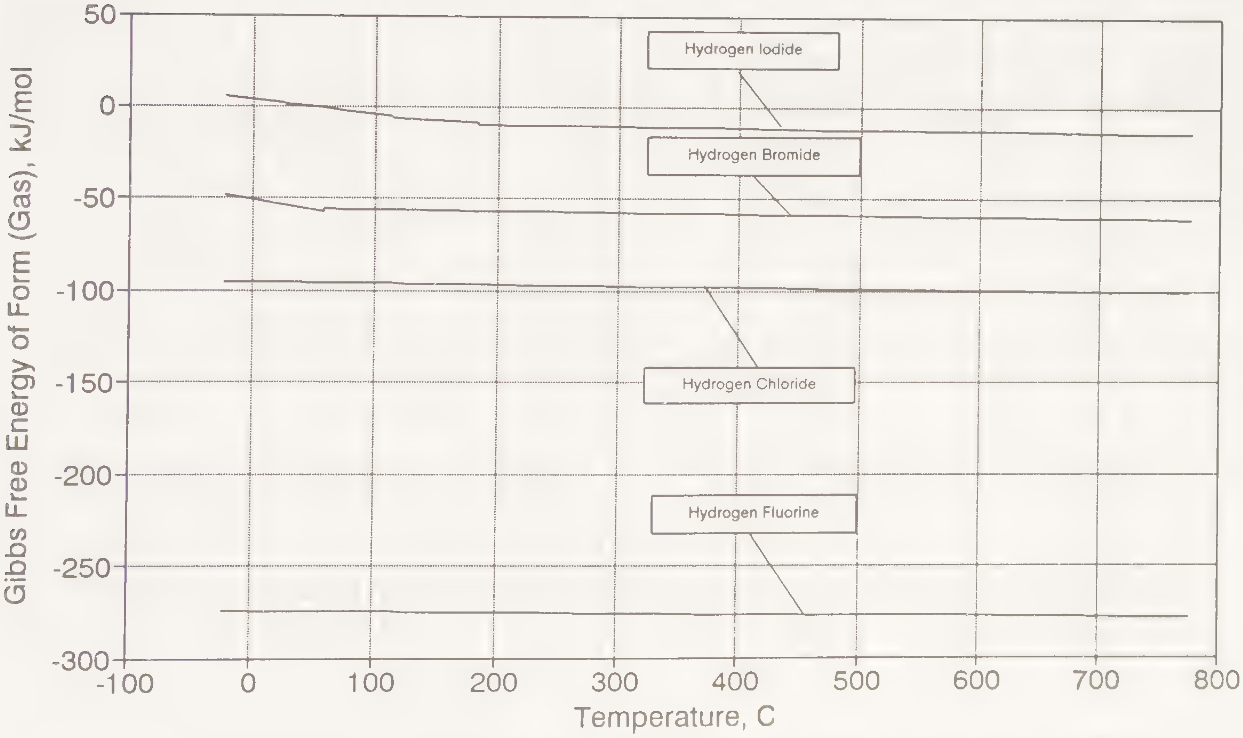

Figure 11-12 Gibbs Free Energy of Formation of Gas

Chapter 12

HALOGENS

Robert W. Gallant, Carl L. Yaws and Xiaoyan Lin

PHYSICAL PROPERTIES - Table 12-1

Property data from the literature (2,3,8,13-18,23-27,31,36,37,39,42,105,106,110,113,116,122,136-148) are given in Table 12-1. The critical constants were selected from the DIPPR project (5). Additional property data are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and data compilations by Yaws and co-workers (31) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 12-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 5% or less in most cases.

HEAT OF VAPORIZATION - Figure 12-2

The data compilation of DIPPR project (5) was selected for heat of vaporization for temperatures ranging from melting point to critical point. A modified Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 12-3

Results from the data compilation of DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 12-4

The data compilation of Yaws and co-workers (31) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 5% or less in most cases.

HEAT CAPACITY - Figures 12-5 and 12-6

Results from the data compilation of Yaws and co-workers (31) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the Yaws and co-workers (31) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 12-7 and 12-8

The data compilation of Yaws and co-workers (31) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7a). Results are in agreement with data. Errors are about 10% or less in most cases.

The data compilation of Yaws and co-workers (31) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8a). Correlation results and data are in fair agreement with errors being about 25% or less.

THERMAL CONDUCTIVITY - Figures 12-9 and 12-10

Results from the data compilation of Yaws and co-workers (31) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9a). Reliability of results is rough with possible errors of 50%.

Results from the data compilation of Yaws and co-workers (31) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10a). Results are in favorable agreement with data. Errors are about 10% or less except for bromine (possible 50%).

ENTHALPY OF FORMATION - Figure 12-11

Results from the DIPPR project (5) and JANAF tables (37) were selected for enthalpy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 12-12

Results from the DIPPR project (5) and JANAF tables (37) were selected for Gibb's free energy of formation of the ideal gas. The data were regressed by a series expansion in temperature, Equation (1-12). Results from the correlation are in favorable agreement with data.

Table 12-1 Physical Properties

1. Name	Fluorine	Chlorine	Bromine	Iodine
2. Formula	F2	Cl2	Br2	I2
3. Molecular Weight, g/mol	37.997	70.905	159.808	253.809
4. Critical Temperature, K	144.31	417.15	584.15	819.15
5. Critical Pressure, bar	52.152	77.108	103.35	116.54
6. Critical Volume, ml/mol	66.20	123.75	135.00	155.00
7. Critical Compressibility Factor	0.288	0.275	0.287	0.265
8. Acentric Factor	0.0588	0.0690	0.1189	0.1171
9. Melting Point, K	53.53	172.12	265.90	386.75
10. Boiling Point @ 1 atm, K	84.95	239.12	331.90	458.39
11. Heat of Vaporization @ BP, kJ/kg	171.71	287.89	187.50	163.65
12. Density of Liquid @ 25 C, g/ml	------	1.398	3.104	------
13. Surface Tension @ 25 C, dynes/cm	------	17.62	40.67	------
14. Heat Capacity of Gas @ 25 C, J/g K	0.827	0.481	0.226	0.146
15. Heat Capacity of Liquid @ 25 C, J/g K	------	0.968	0.383	------
16. Viscosity of Gas @ 25 C, micropoise	232.56	133.53	153.78	136.51
17. Viscosity of Liquid @ 25 C, centipoise	------	0.343	0.949	------
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0281	0.0092	0.0050	0.0036
19. Thermal Conductivity of Liquid @ 25 C, W/m K	------	0.1337	0.1270	------
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	------	------	------	------
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	------	------	------	------
22. Flash Point, K	------	------	------	------
23. Autoignition Temperature, K	------	------	------	------
24. Lower Explosion Limit in Air, vol %	------	------	------	------
25. Upper Explosion Limit in Air, vol %	------	------	------	------
26. Solubility in Water @ 25 C, ppm(wt)	------	14,744	------	------

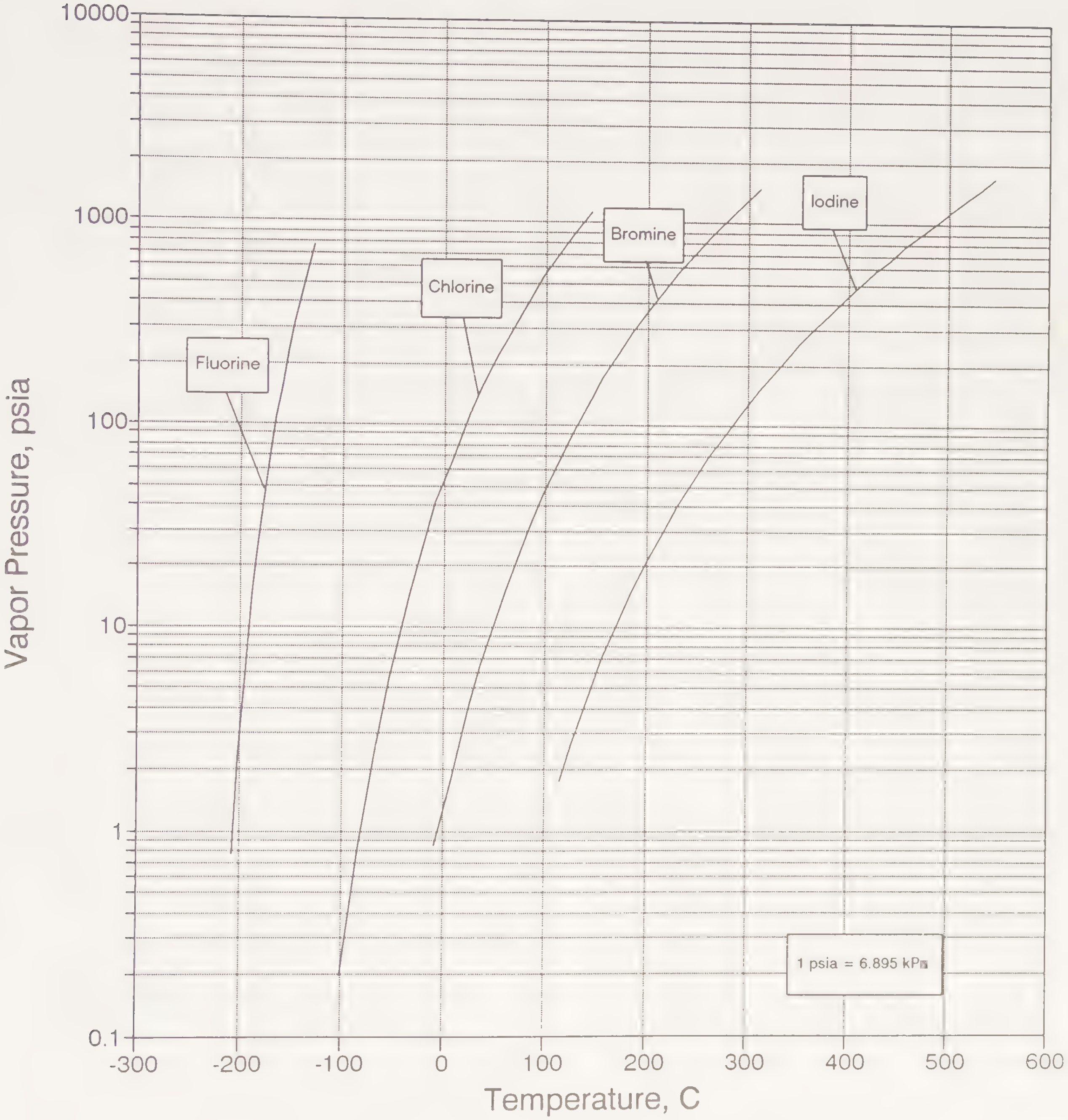

Figure 12-1 Vapor Pressure

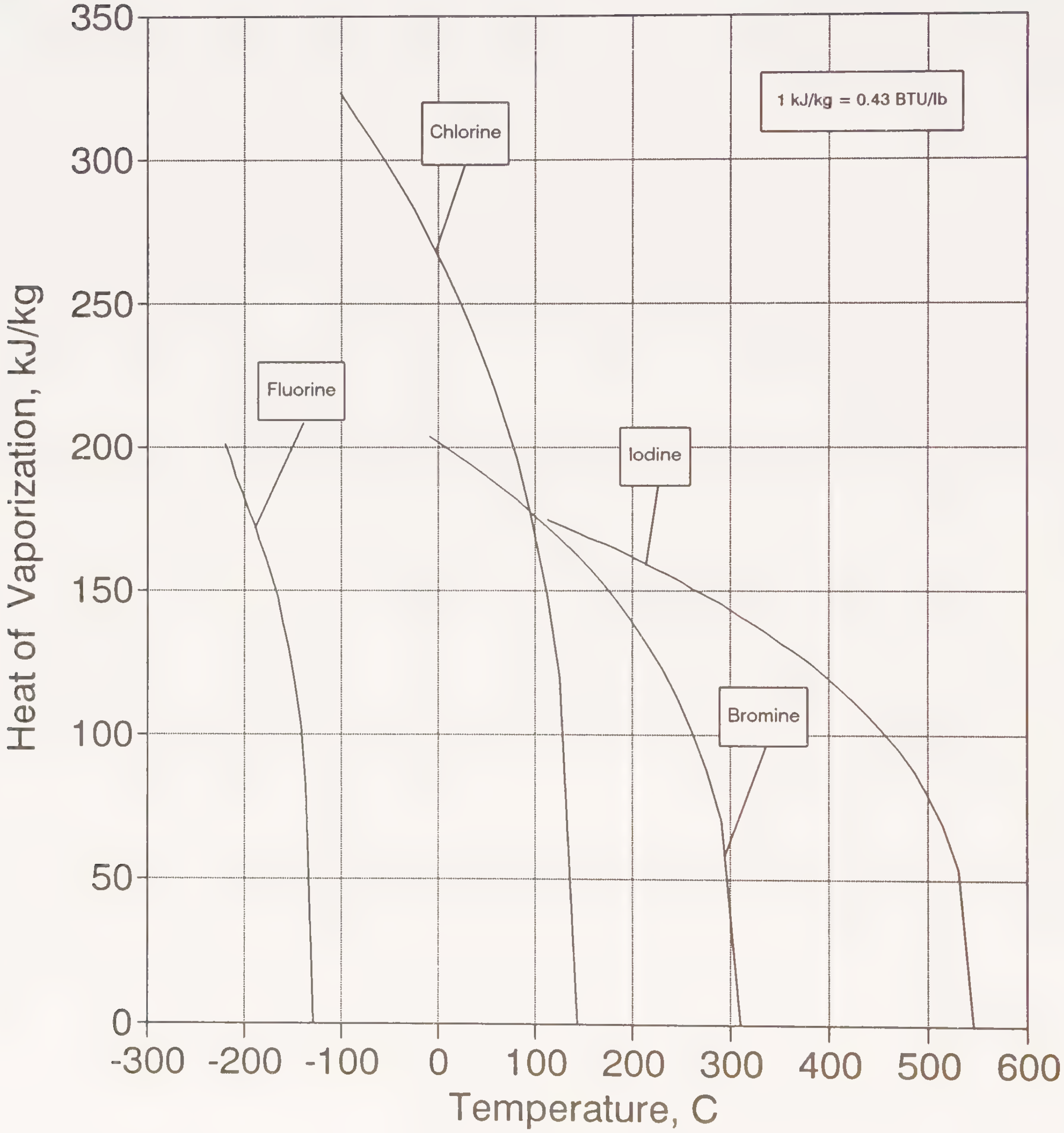

Figure 12-2 Heat of Vaporization

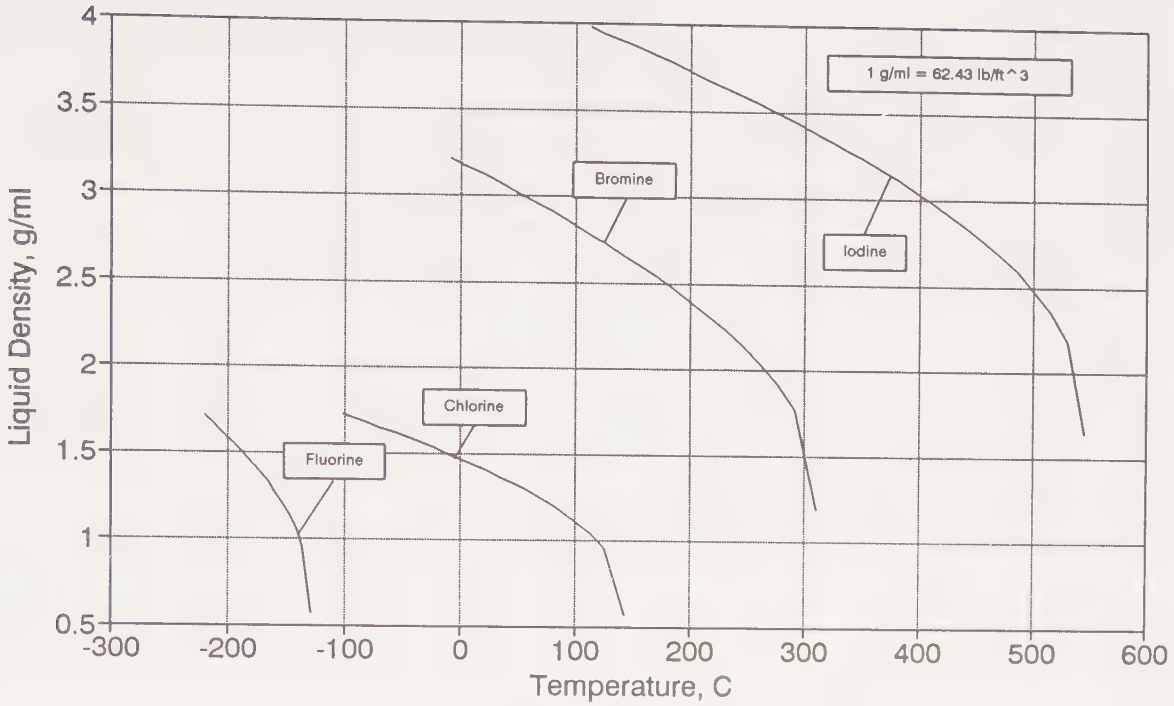

Figure 12-3 Liquid Density

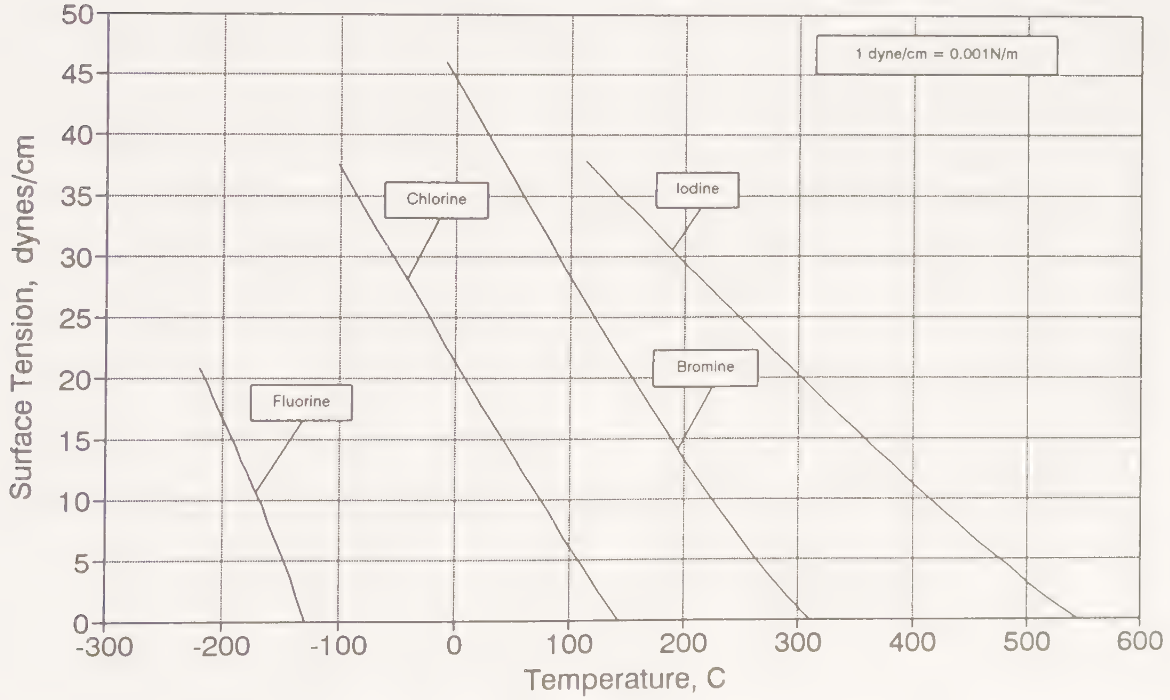

Figure 12-4 Surface Tension

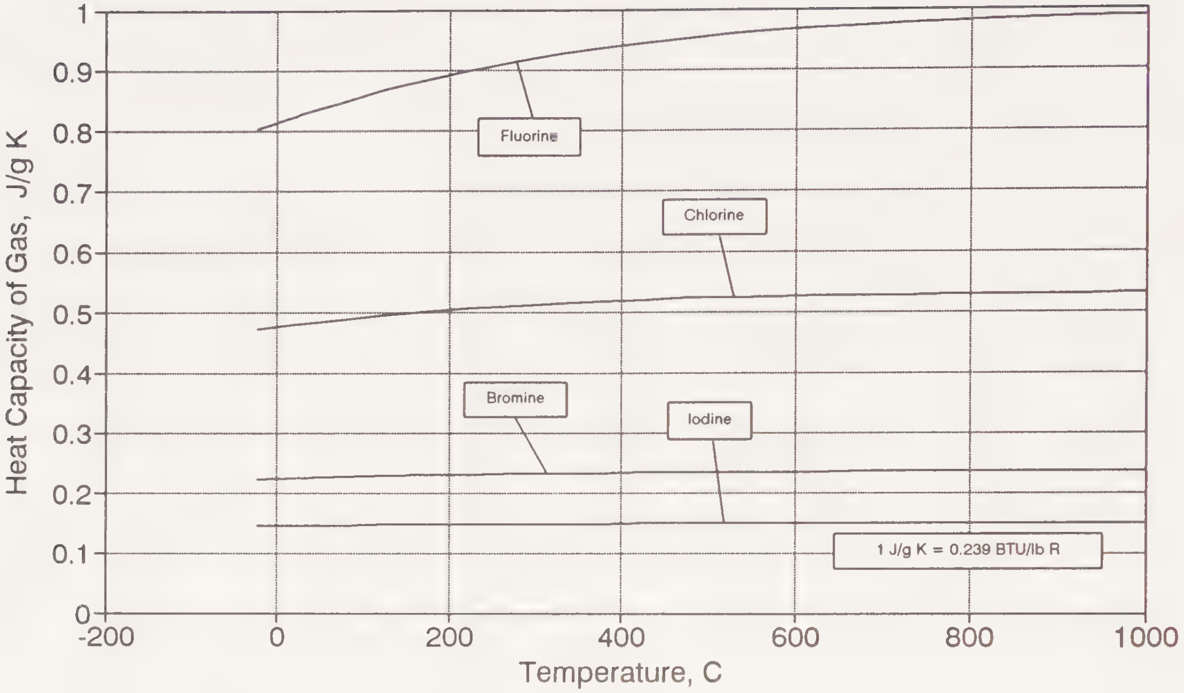

Figure 12-5 Heat Capacity of Gas

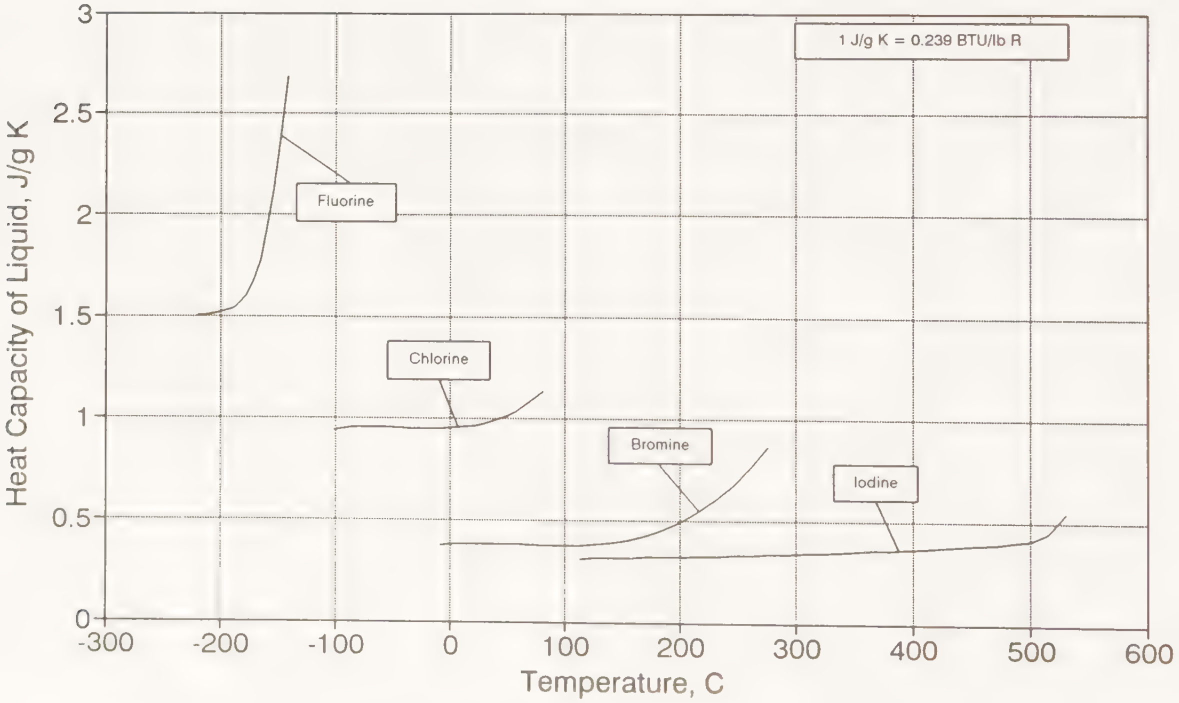

Figure 12-6 Heat Capacity of Liquid

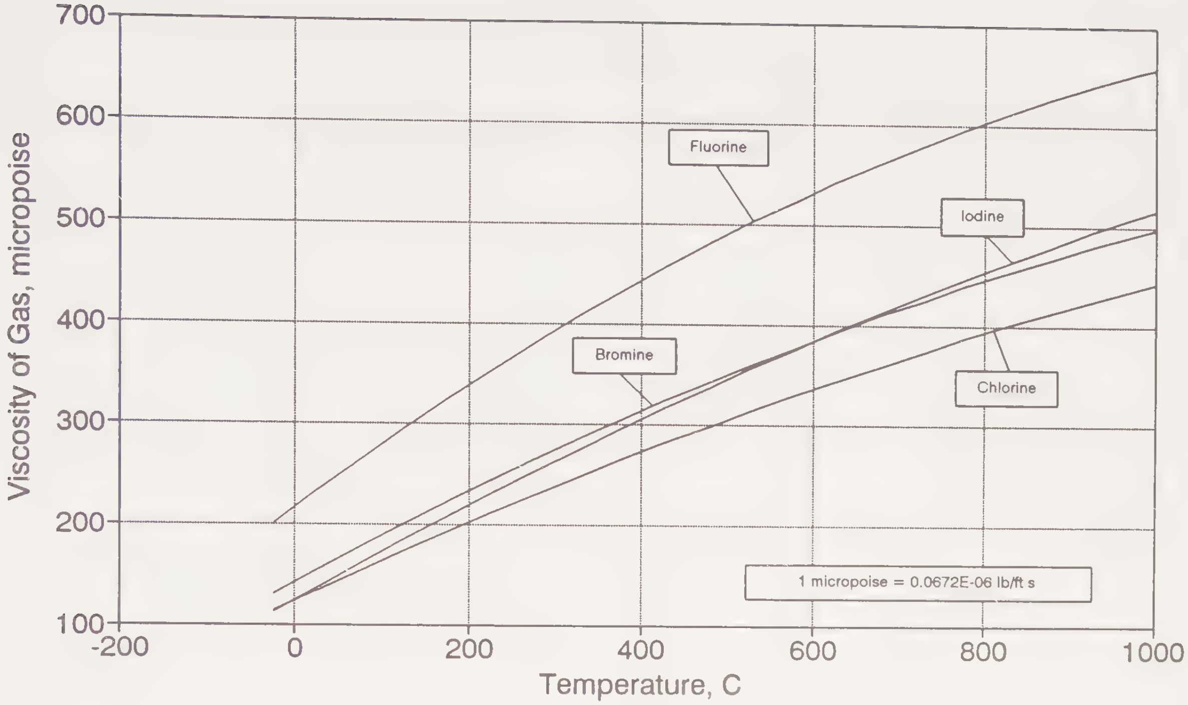

Figure 12-7 Viscosity of Gas

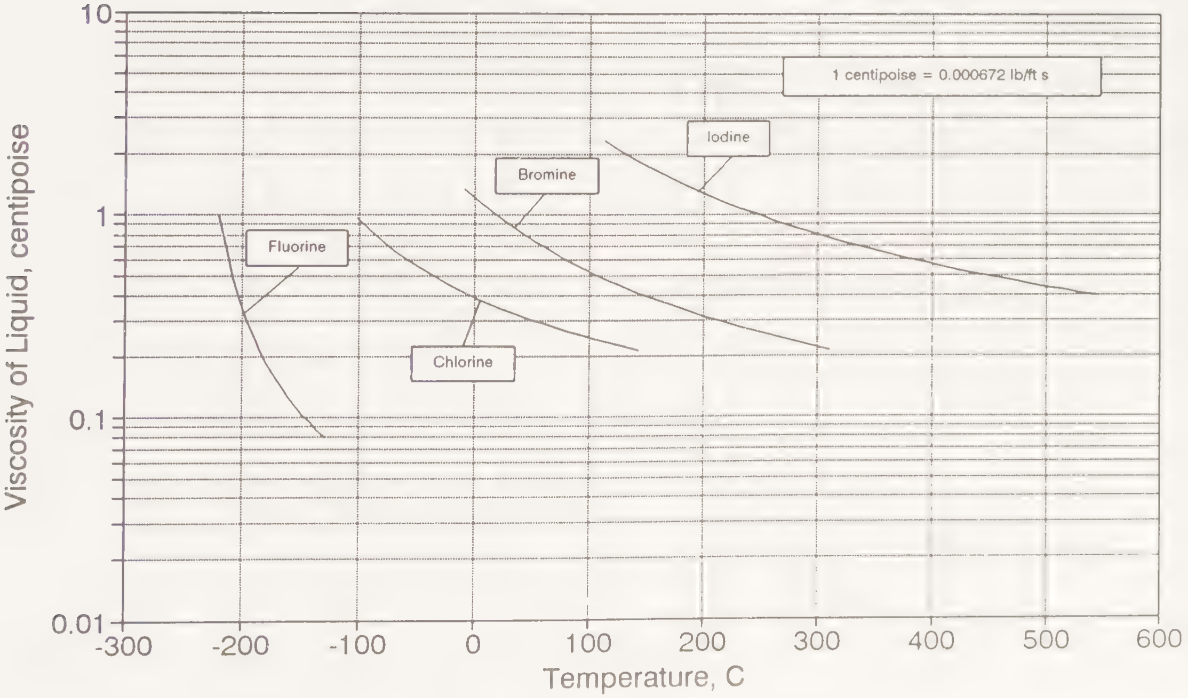

Figure 12-8 Viscosity of Liquid

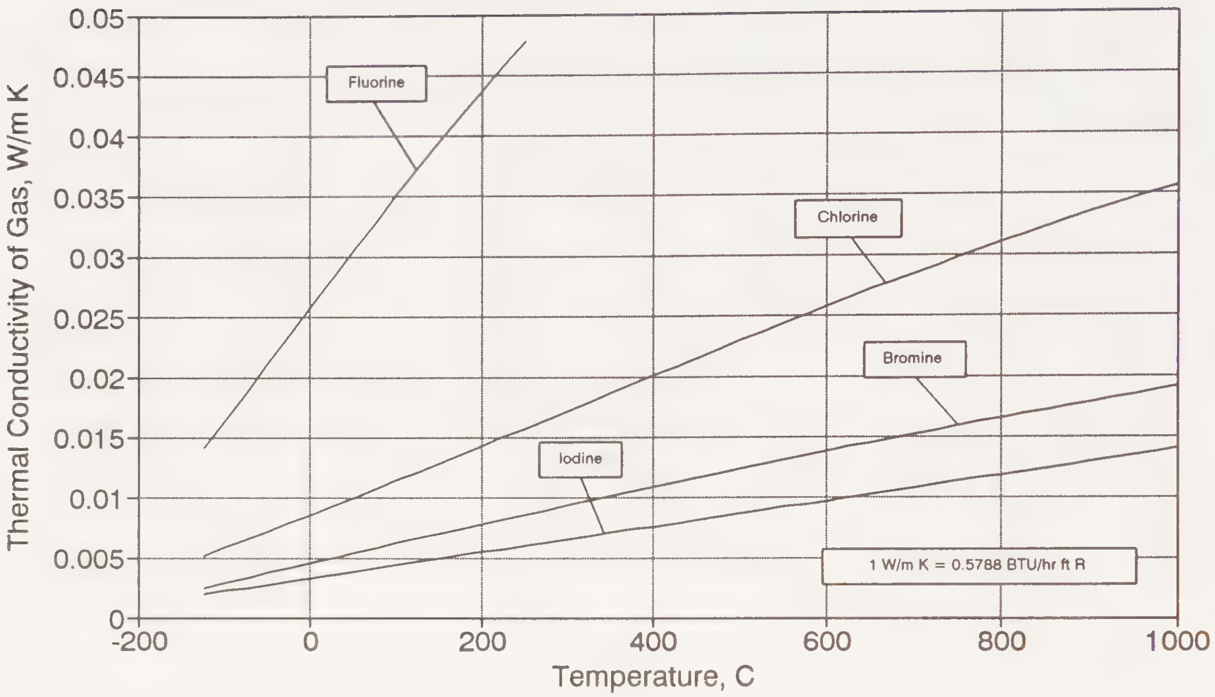

Figure 12-9 Thermal Conductivity of Gas

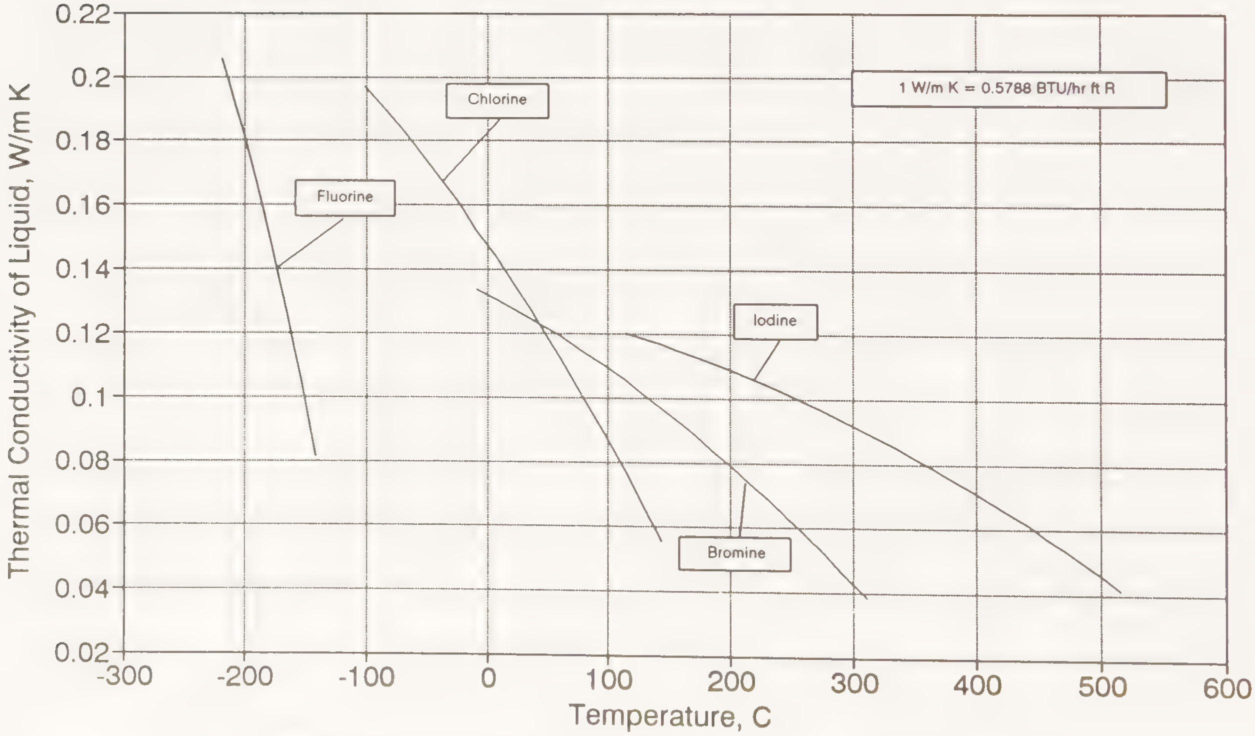

Figure 12-10 Thermal Conductivity of Liquid

Chapter 13

C_{10}, C_{12} AND C_{14} NORMAL ALKANES

Robert W. Gallant, Carl L. Yaws and Xiaoyan Lin

PHYSICAL PROPERTIES - Table 13-1

Property data from the literature (1-23,25-36,38-59,72-88) are given in Table 13-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation, lower explosion limit in air and solubility in water are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 13-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 13-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 13-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 2% in most cases.

SURFACE TENSION - Figure 13-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 13-5 and 13-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 3% or less using the correlation.

VISCOSITY - Figures 13-7 and 13-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 13-9 and 13-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 3% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

ENTHALPY OF FORMATION - Figure 13-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 13-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 13-1 Physical Properties

1. Name	Decane	Dodecane	Tetradecane
2. Formula	C10H22	C12H26	C14H30
3. Molecular Weight, g/mol	142.284	170.337	198.391
4. Critical Temperature, K	618.45	658.20	692.40
5. Critical Pressure, bar	21.229	18.239	15.400
6. Critical Volume, ml/mol	603.12	713.00	842.80
7. Critical Compressibility Factor	0.249	0.238	0.225
8. Acentric Factor	0.4842	0.5752	0.6413
9. Melting Point, K	243.51	263.57	279.01
10. Boiling Point @ 1 atm, K	447.30	489.47	526.73
11. Heat of Vaporization @ BP, kJ/kg	275.82	255.69	239.65
12. Density of Liquid @ 25 C, g/ml	0.727	0.744	0.758
13. Surface Tension @ 25 C, dynes/cm	23.39	24.93	26.16
14. Heat Capacity of Gas @ 25 C, J/g K	1.647	1.644	1.642
15. Heat Capacity of Liquid @ 25 C, J/g K	2.197	2.201	2.214
16. Viscosity of Gas @ 25 C, micropoise	47.46	41.05	36.58
17. Viscosity of Liquid @ 25 C, centipoise	0.872	1.407	2.128
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1318	0.1515	0.1363
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-249.92	-291.18	-332.49
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	32.46	49.17	65.82
22. Flash Point, K	319.26	347.04	373.15
23. Autoignition Temperature, K	480.93	477.04	475.37
24. Lower Explosion Limit in Air, vol %	0.8	0.6	0.5
25. Upper Explosion Limit in Air, vol %	5.4	------	------
26. Solubility in Water @ 25 C, ppm(wt)	0.052	0.0037	0.0020

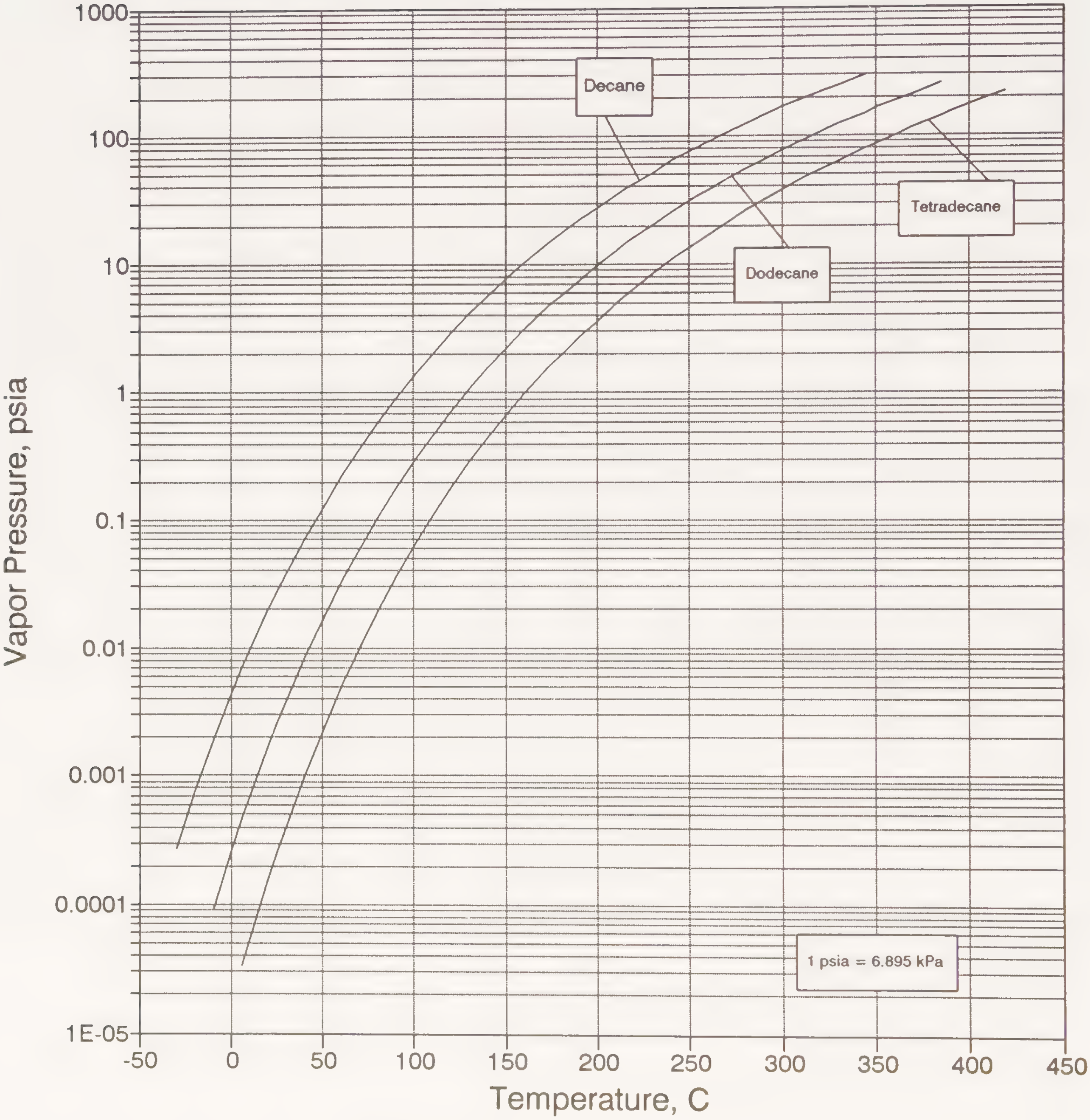

Figure 13-1 Vapor Pressure

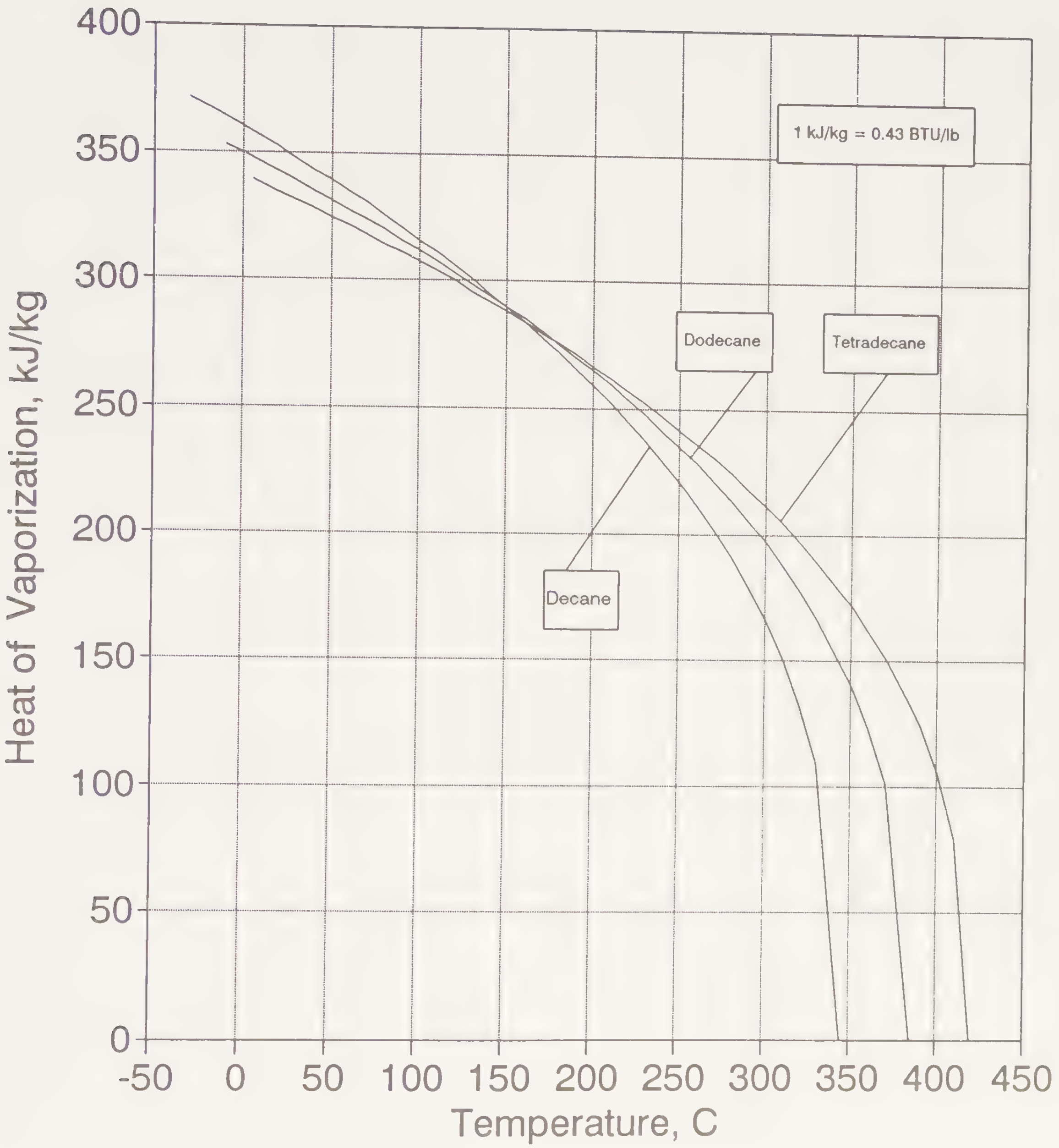

Figure 13-2 Heat of Vaporization

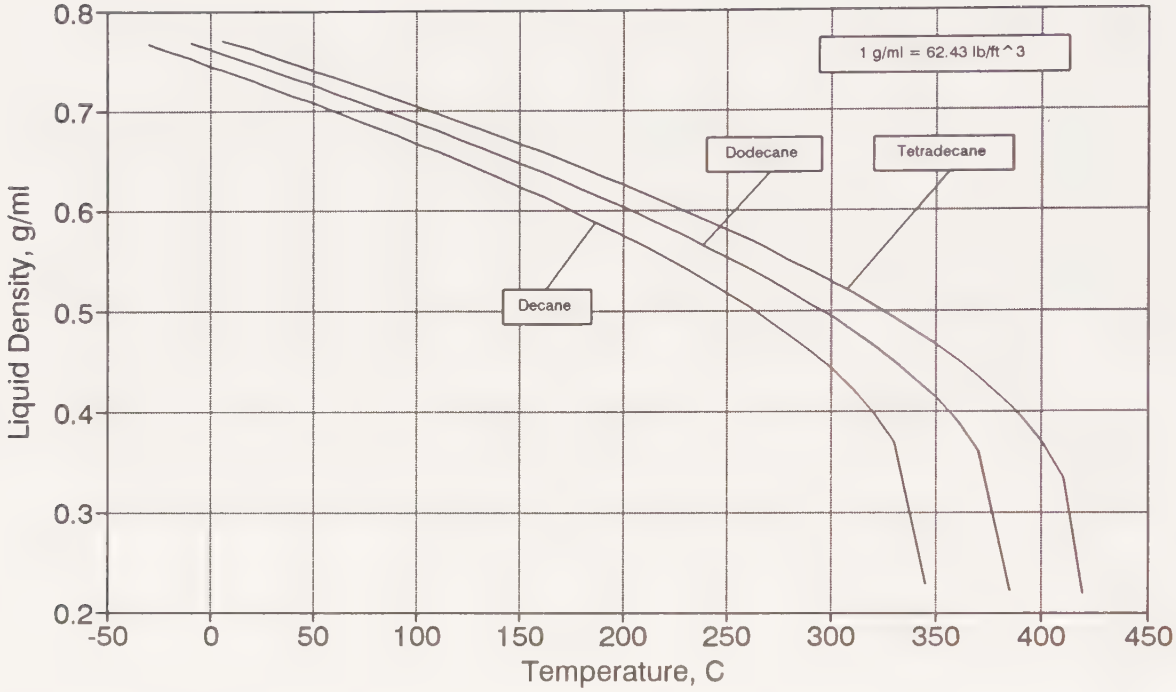

Figure 13-3 Liquid Density

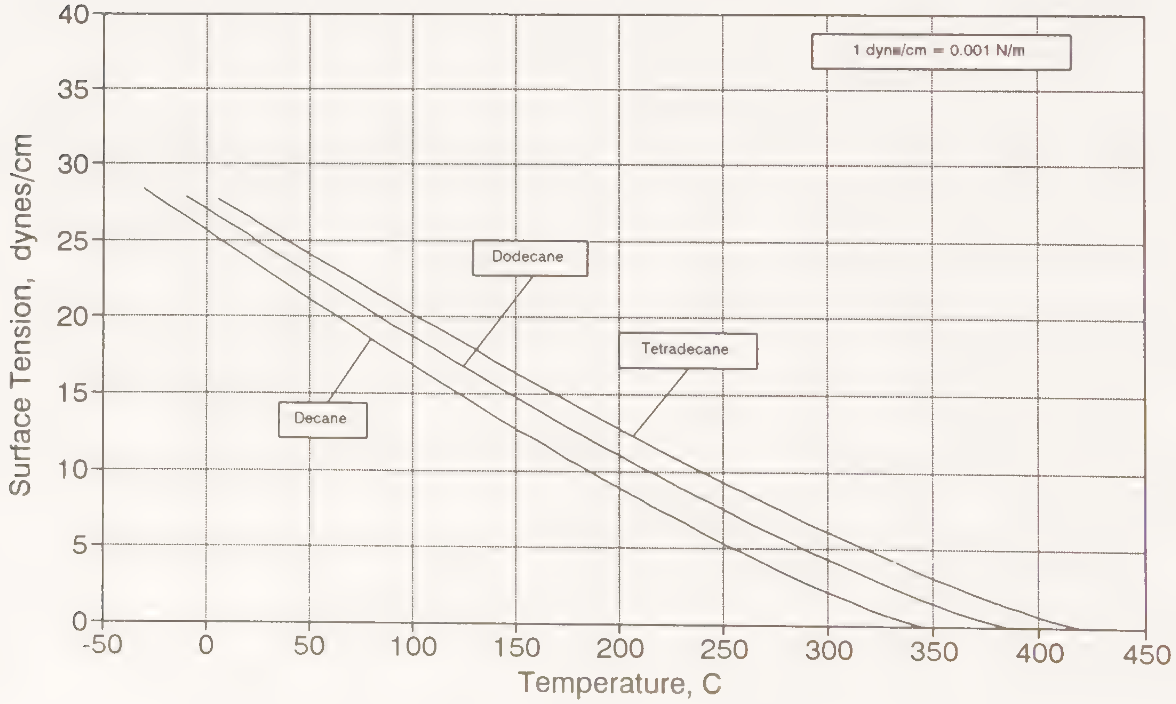

Figure 13-4 Surface Tension

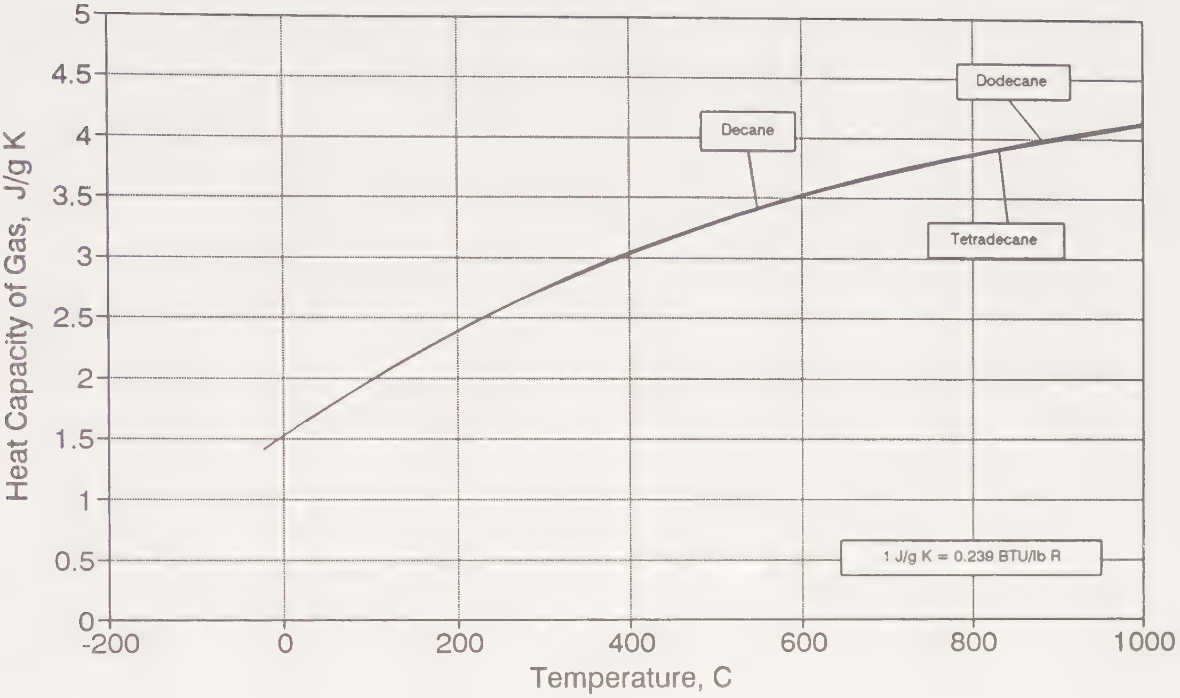

Figure 13-5 Heat Capacity of Gas

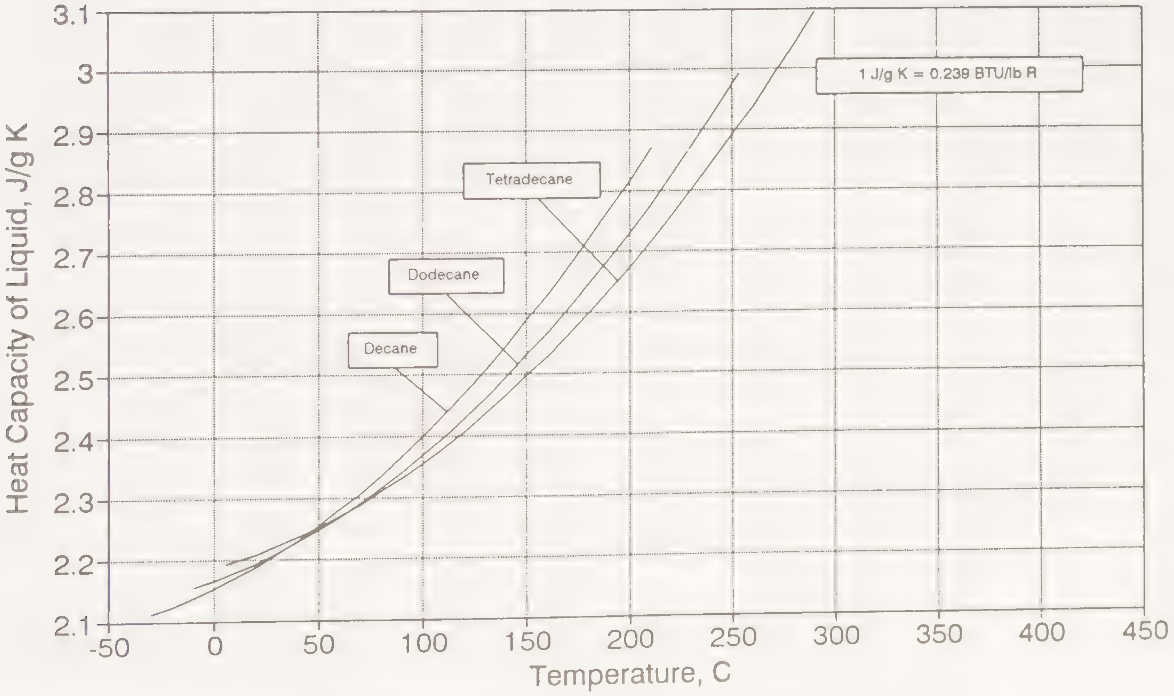

Figure 13-6 Heat Capacity of Liquid

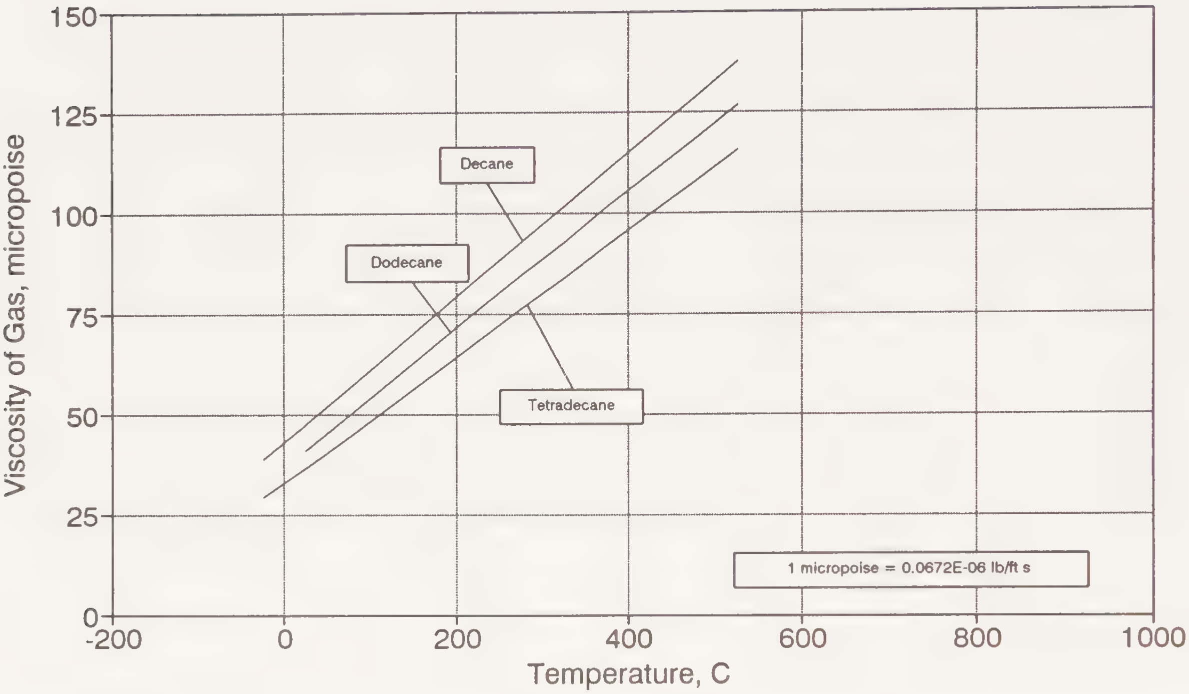

Figure 13-7 Viscosity of Gas

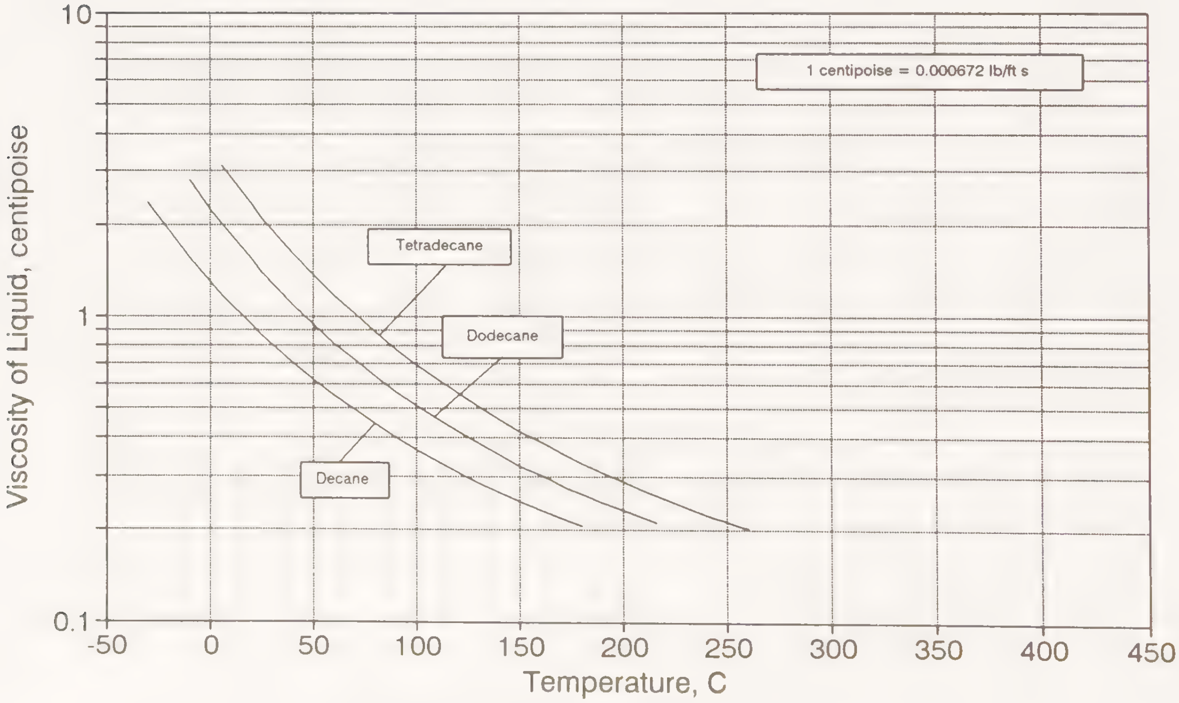

Figure 13-8 Viscosity of Liquid

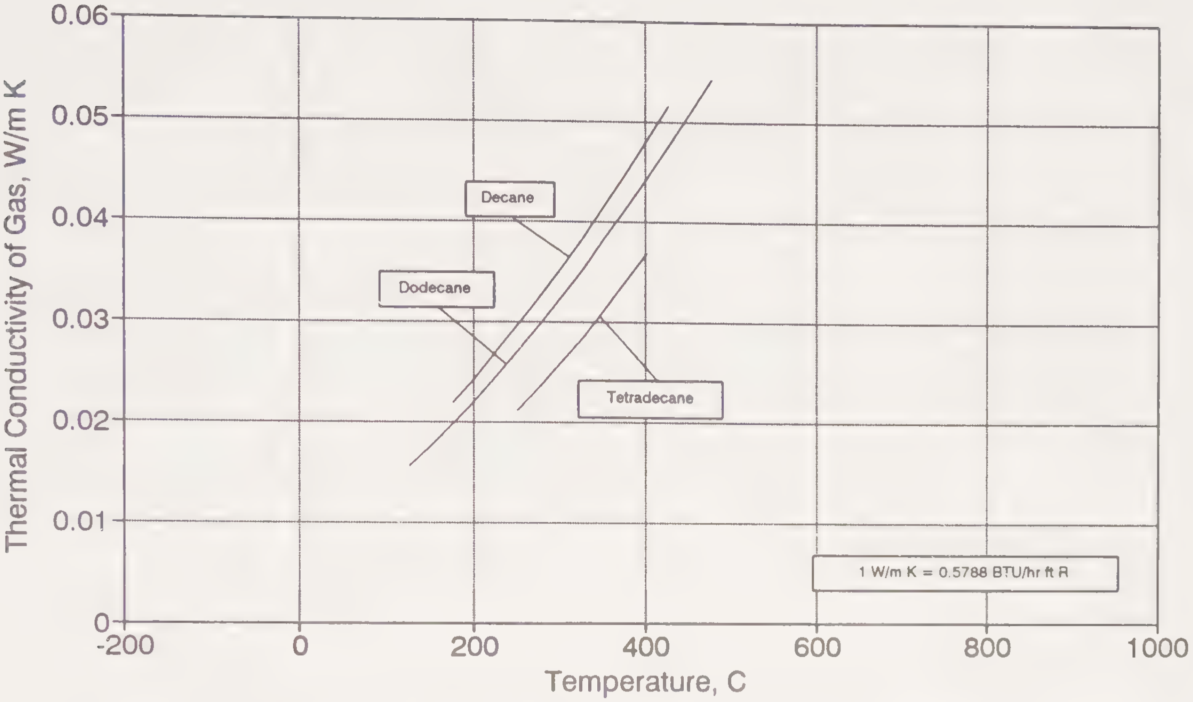

Figure 13-9 Thermal Conductivity of Gas

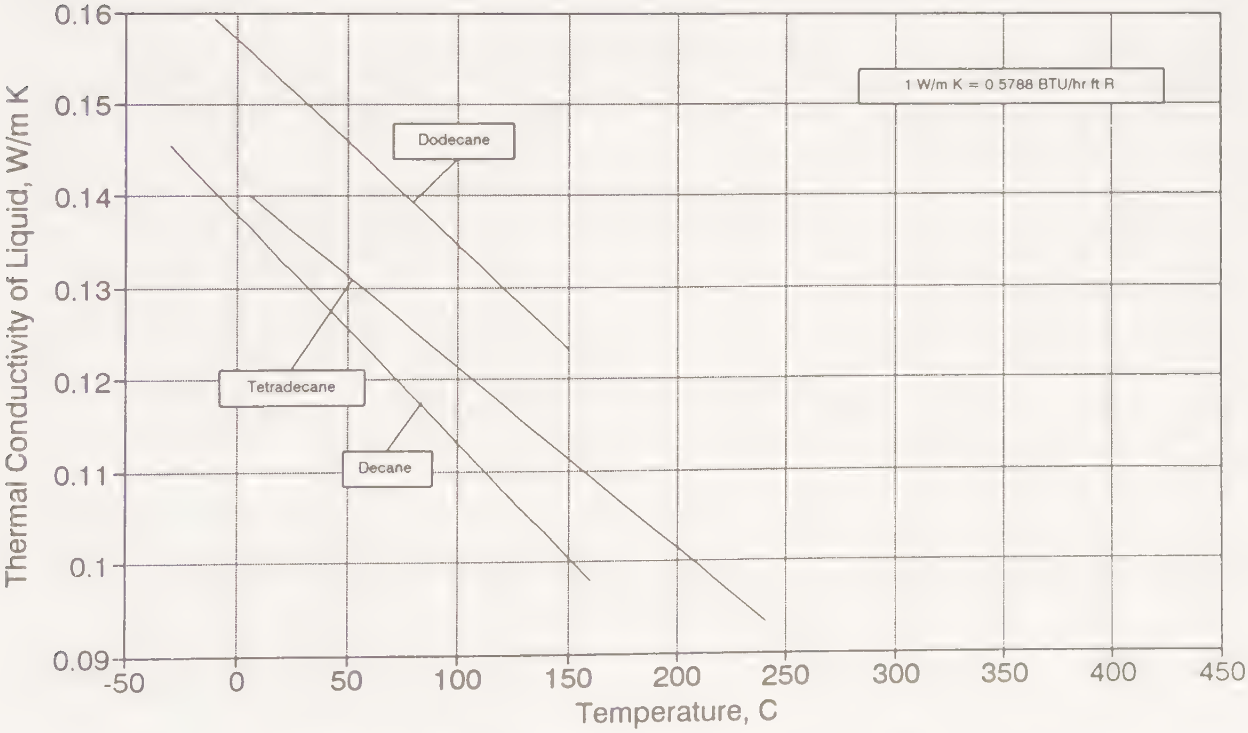

Figure 13-10 Thermal Conductivity of Liquid

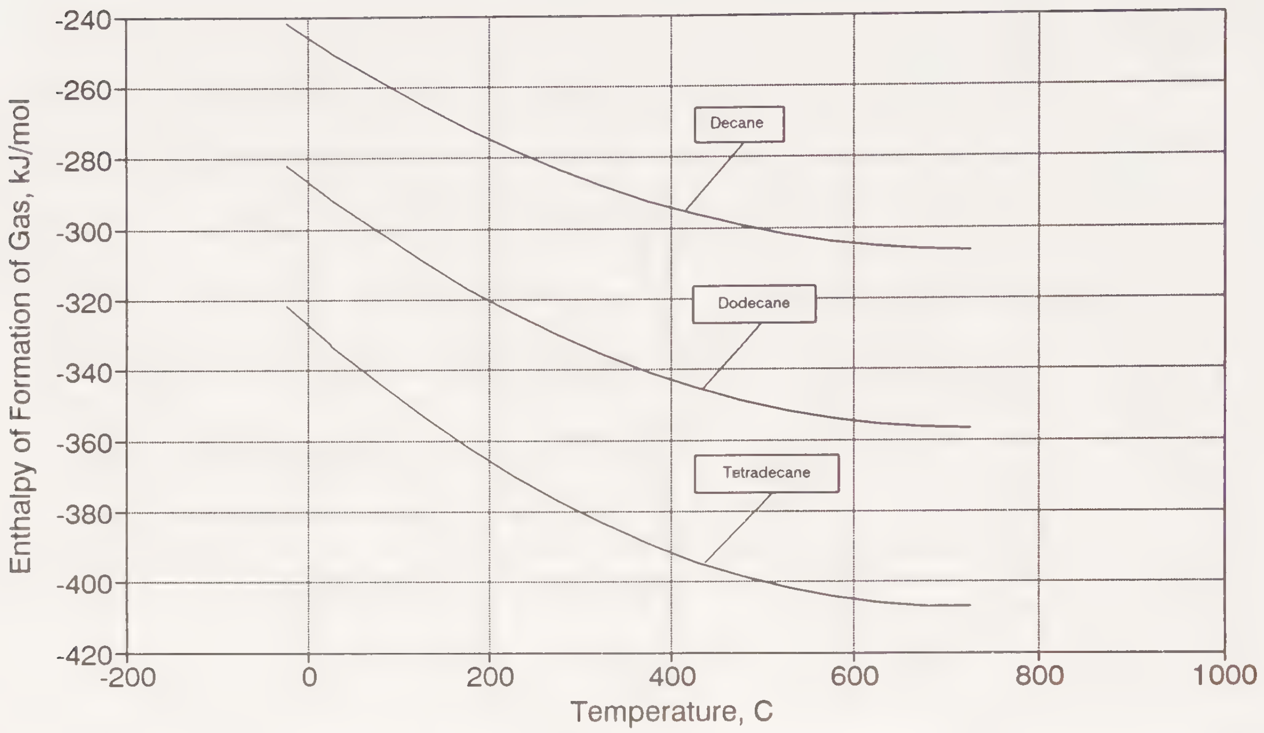

Figure 13-11 Enthalpy of Formation of Gas

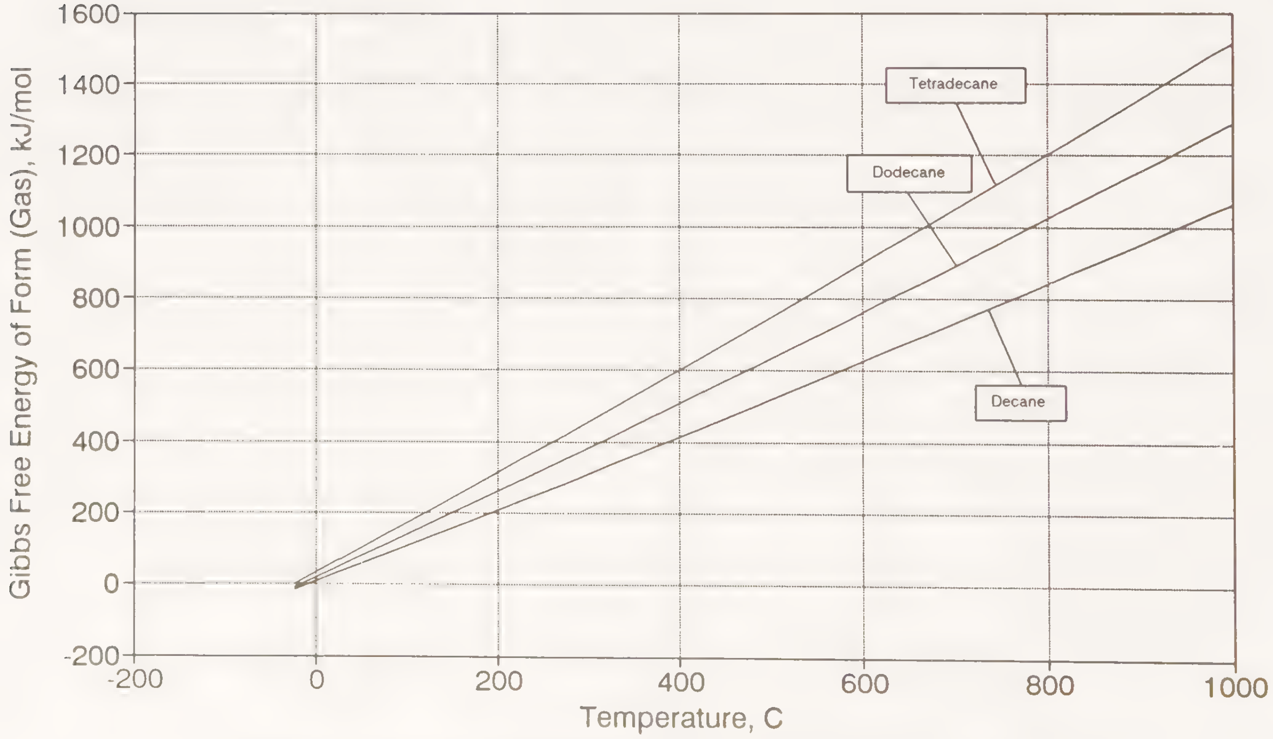

Figure 13-12 Gibbs Free Energy of Formation of Gas

Chapter 14

C_{16}, C_{18} AND C_{20} NORMAL ALKANES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 14-1

Property data from the literature (1-23,25-36,38-59,72-74,78,79,85,88,139,155-168) are given in Table 14-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation, lower explosion limit in air and solubility in water are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 14-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 14-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 14-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 2% in most cases.

SURFACE TENSION - Figure 14-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 14-5 and 14-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 3% or less using the correlation.

VISCOSITY - Figures 14-7 and 14-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 14-9 and 14-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 3% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

ENTHALPY OF FORMATION - Figure 14-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 14-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 14-1 Physical Properties

1. Name	Hexadecane	Octadecane	Eicosane
2. Formula	C16H34	C18H38	C20H42
3. Molecular Weight, g/mol	226.446	254.500	282.553
4. Critical Temperature, K	720.60	745.26	767.04
5. Critical Pressure, bar	14.186	12.135	10.400
6. Critical Volume, ml/mol	930.0	1070.0	1190.0
7. Critical Compressibility Factor	0.220	0.210	0.194
8. Acentric Factor	0.7471	0.7951	0.8764
9. Melting Point, K	291.34	301.33	309.59
10. Boiling Point @ 1 atm, K	560.01	589.86	616.93
11. Heat of Vaporization @ BP, kJ/kg	226.42	213.86	203.50
12. Density of Liquid @ 28 C, g/ml	0.764	0.777	------
13. Surface Tension @ 28 C, dynes/cm	26.68	27.51	------
14. Heat Capacity of Gas @ 25 C, J/g K	1.640	1.639	1.638
15. Heat Capacity of Liquid @ 28 C, J/g K	2.232	2.141	------
16. Viscosity of Gas @ 25 C, micropoise	33.77	------	------
17. Viscosity of Liquid @ 28 C, centipoise	2.83	3.87	------
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 28 C, W/m K	0.1400	0.1499	------
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-373.76	-415.01	-456.31
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	82.52	99.22	115.92
22. Flash Point, K	399.00	420.00	442.00
23. Autoignition Temperature, K	475.15	508.15	475.00
24. Lower Explosion Limit in Air, vol %	0.5	0.4	0.4
25. Upper Explosion Limit in Air, vol %	4.7	------	------
26. Solubility in Water @ 25 C, ppm(wt)	0.0009	0.0021	0.0019

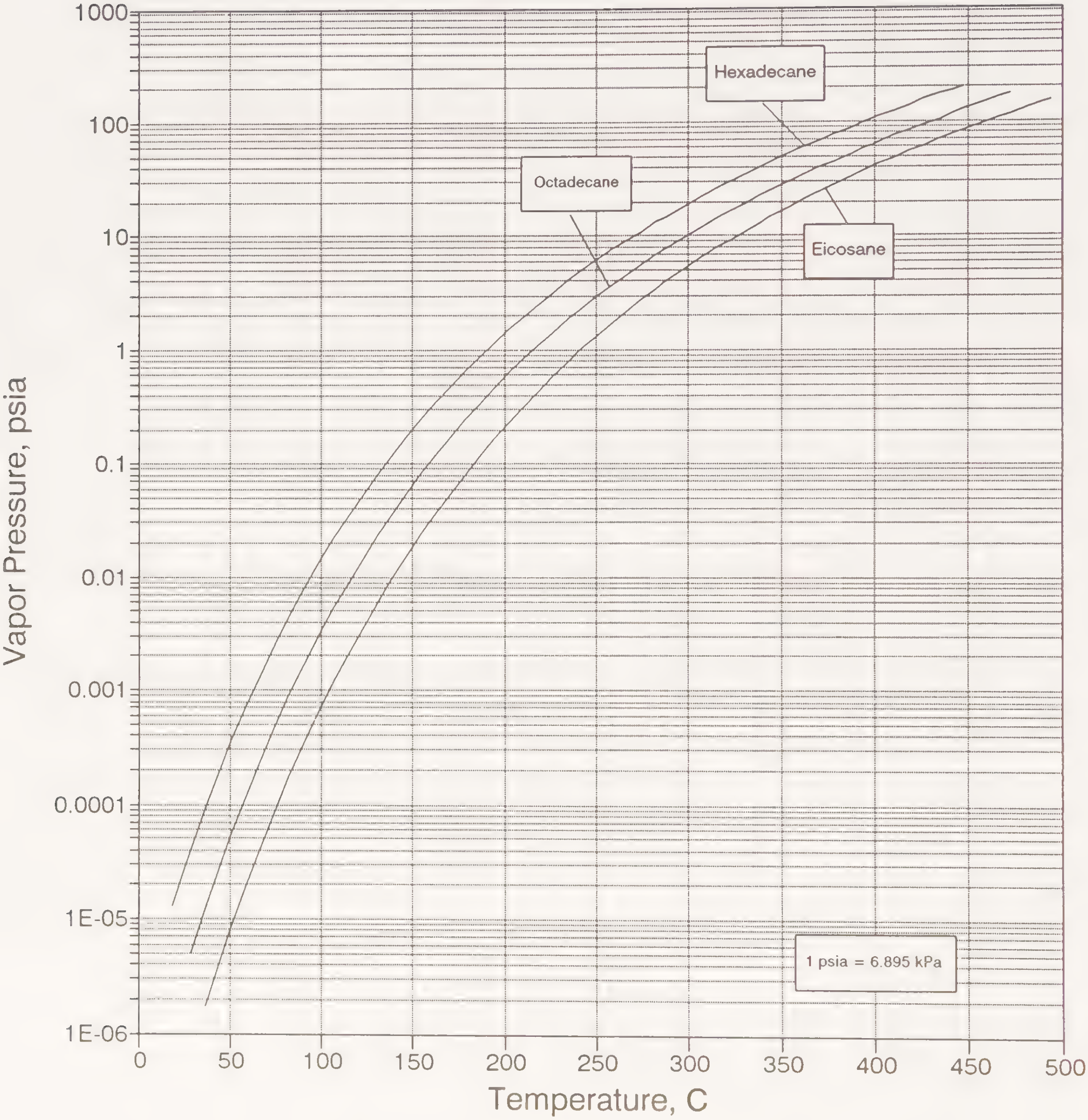

Figure 14-1 Vapor Pressure

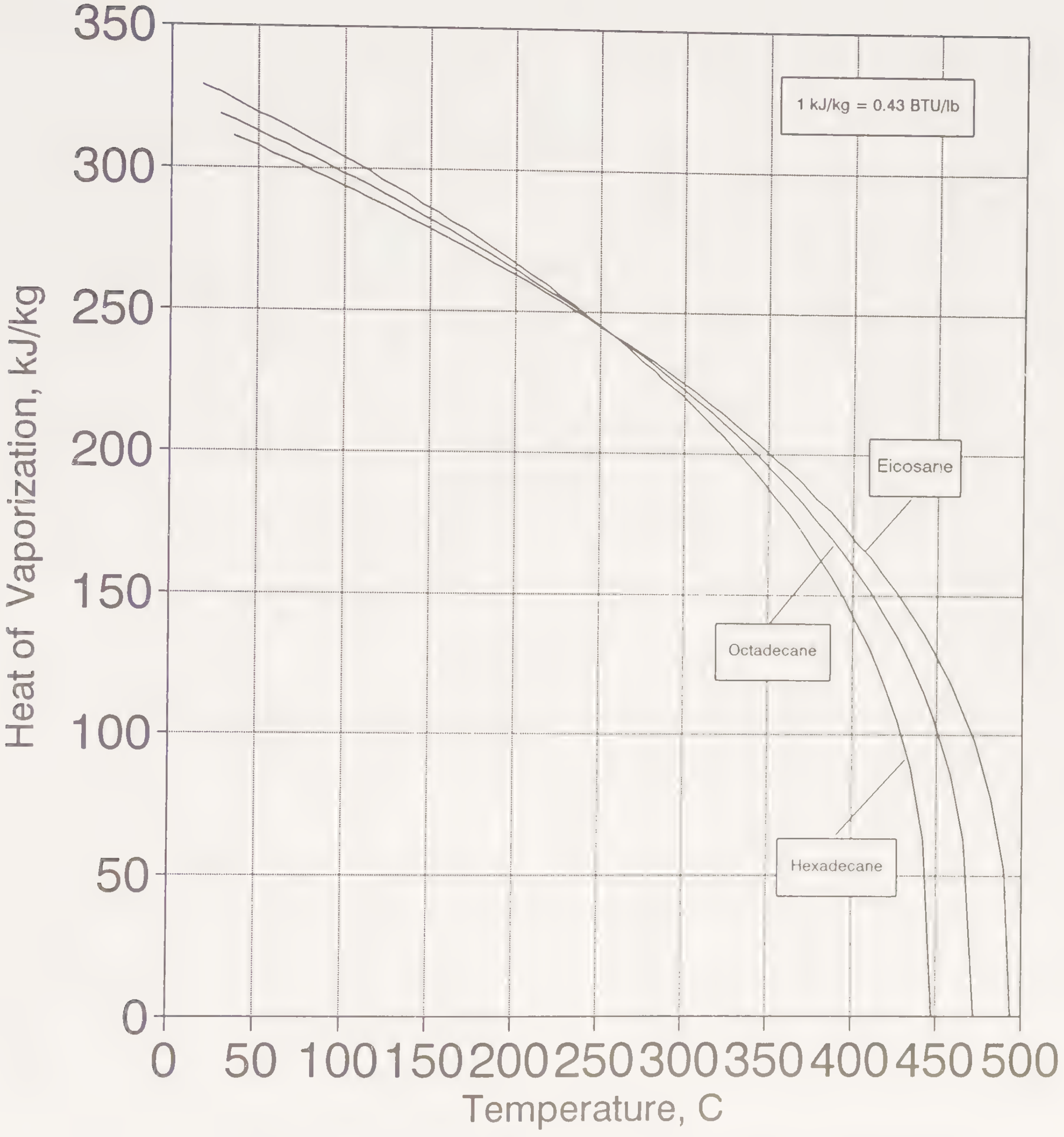

Figure 14-2 Heat of Vaporization

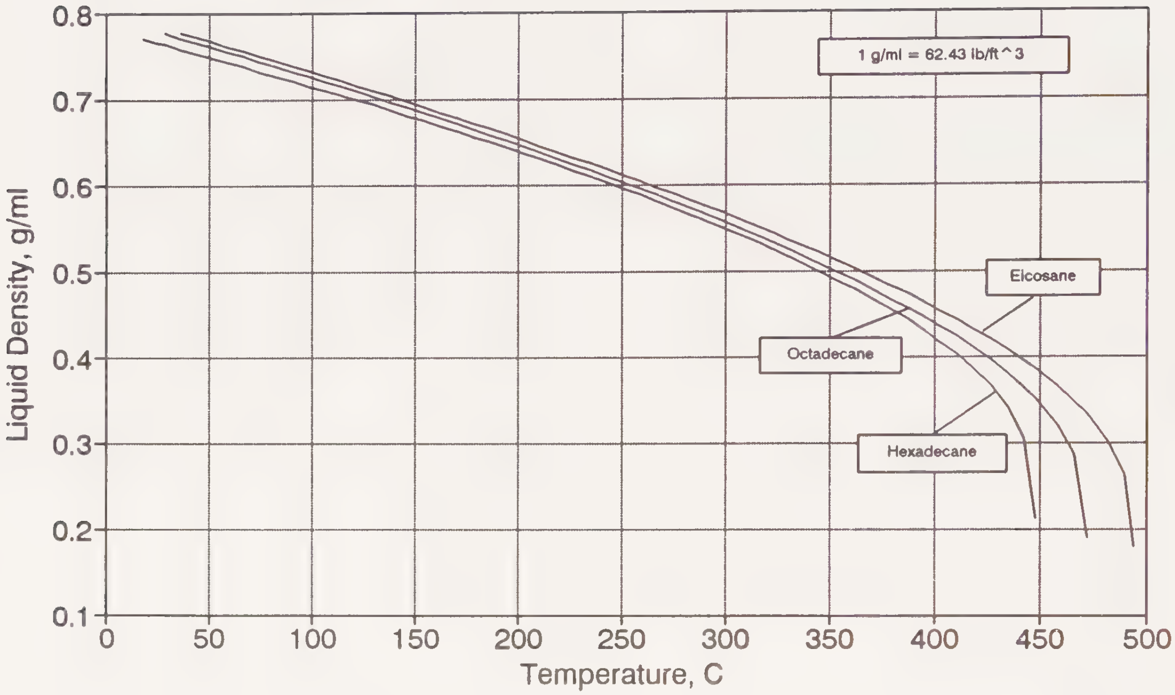

Figure 14-3 Liquid Density

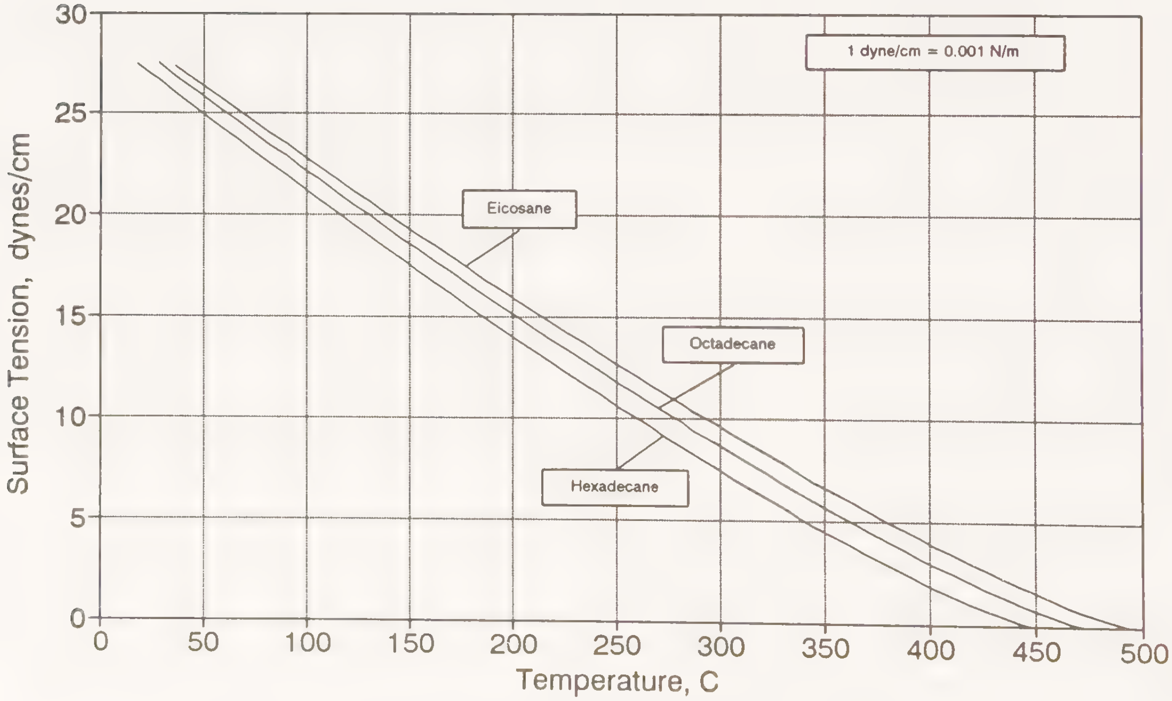

Figure 14-4 Surface Tension

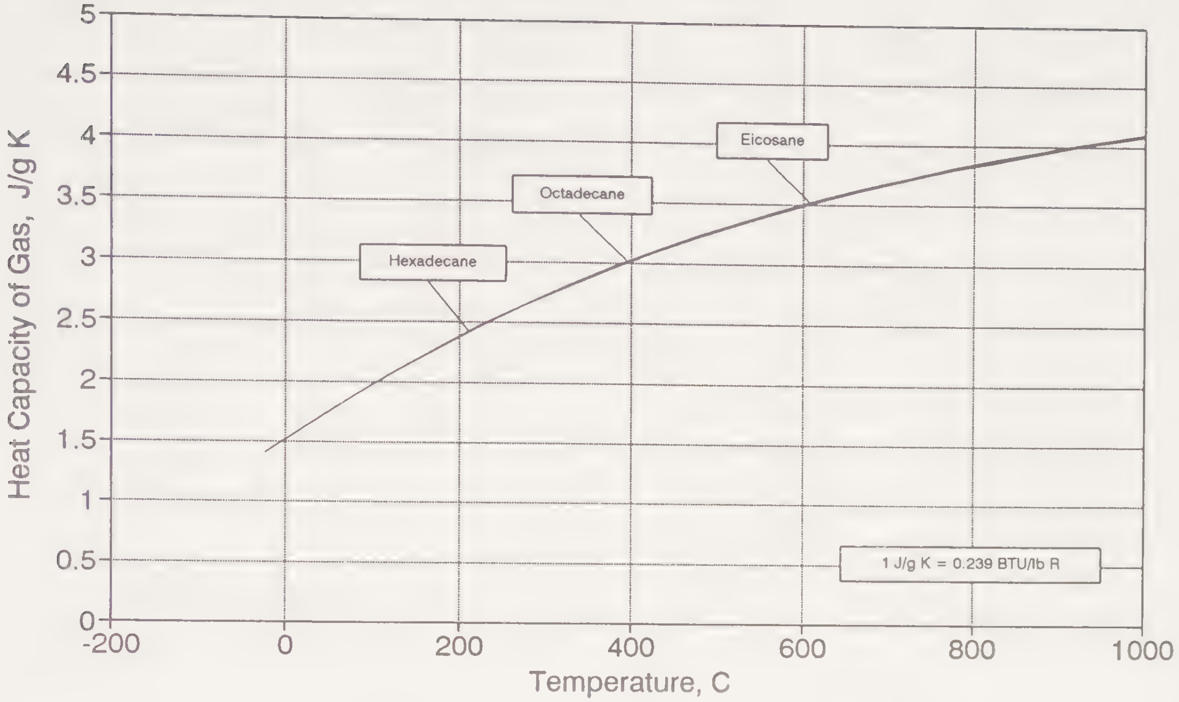

Figure 14-5 Heat Capacity of Gas

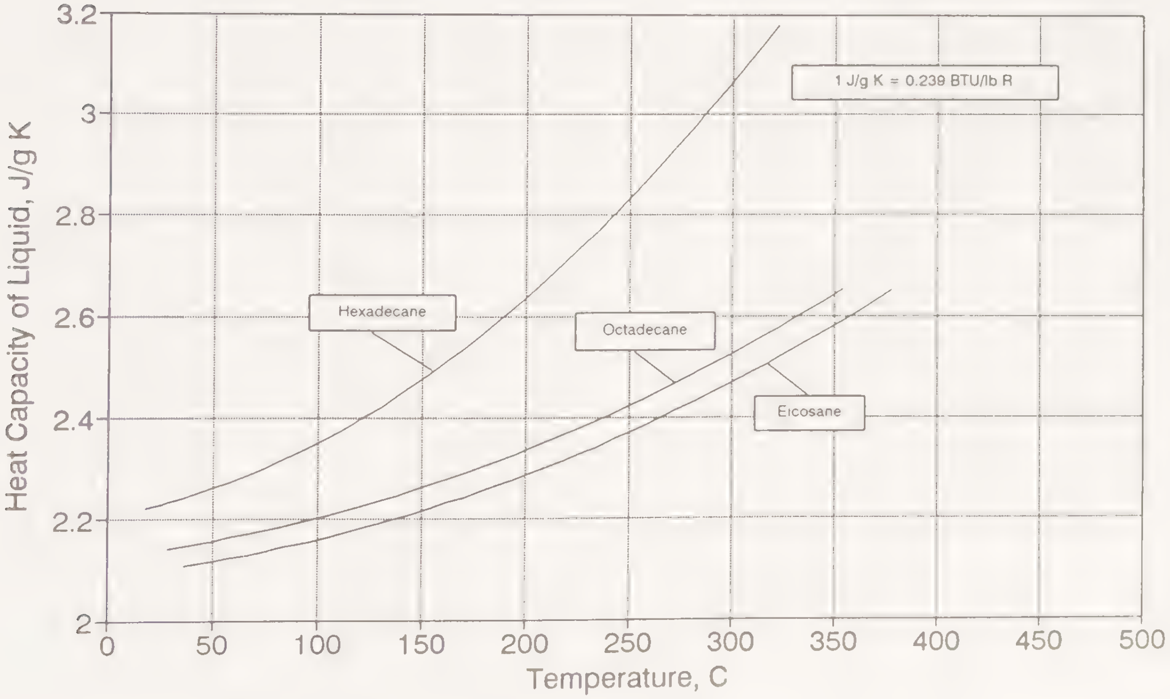

Figure 14-6 Heat Capacity of Liquid

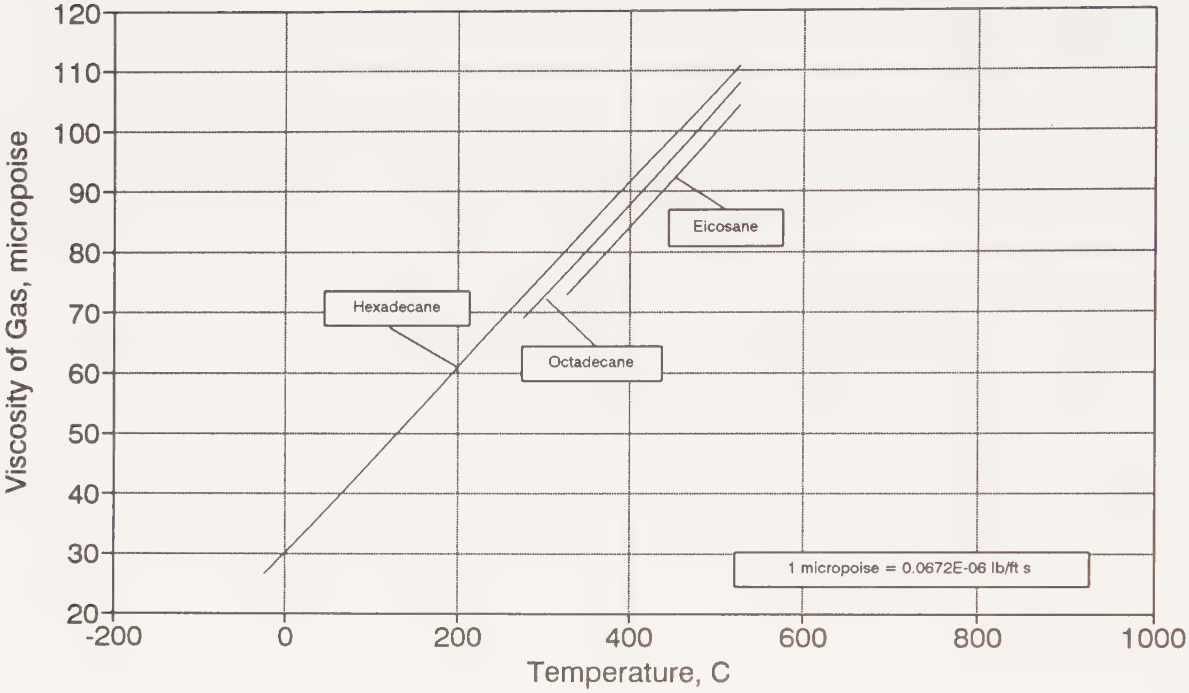

Figure 14-7 Viscosity of Gas

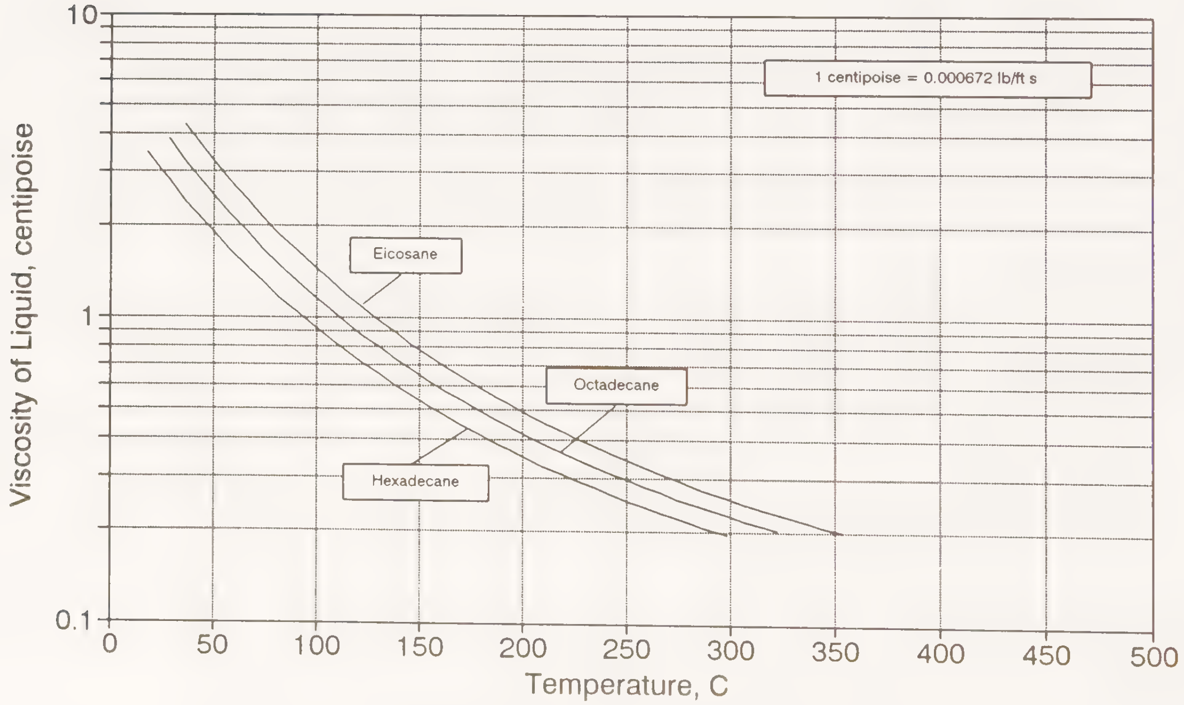

Figure 14-8 Viscosity of Liquid

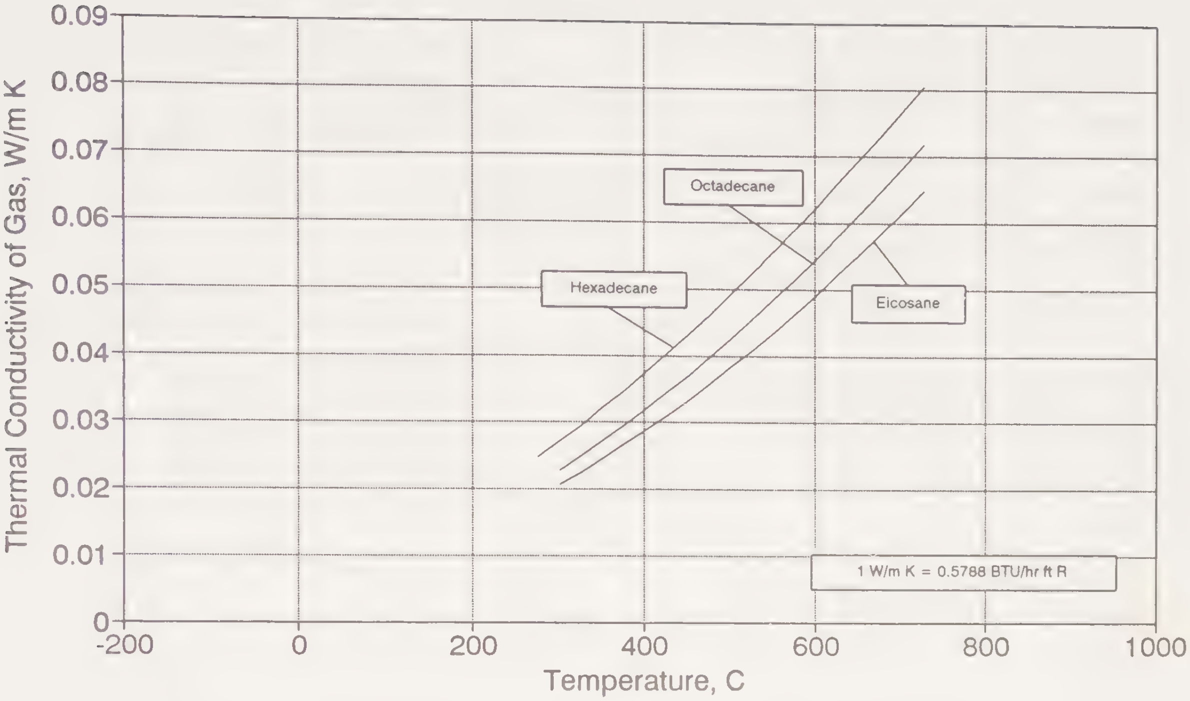

Figure 14-9 Thermal Conductivity of Gas

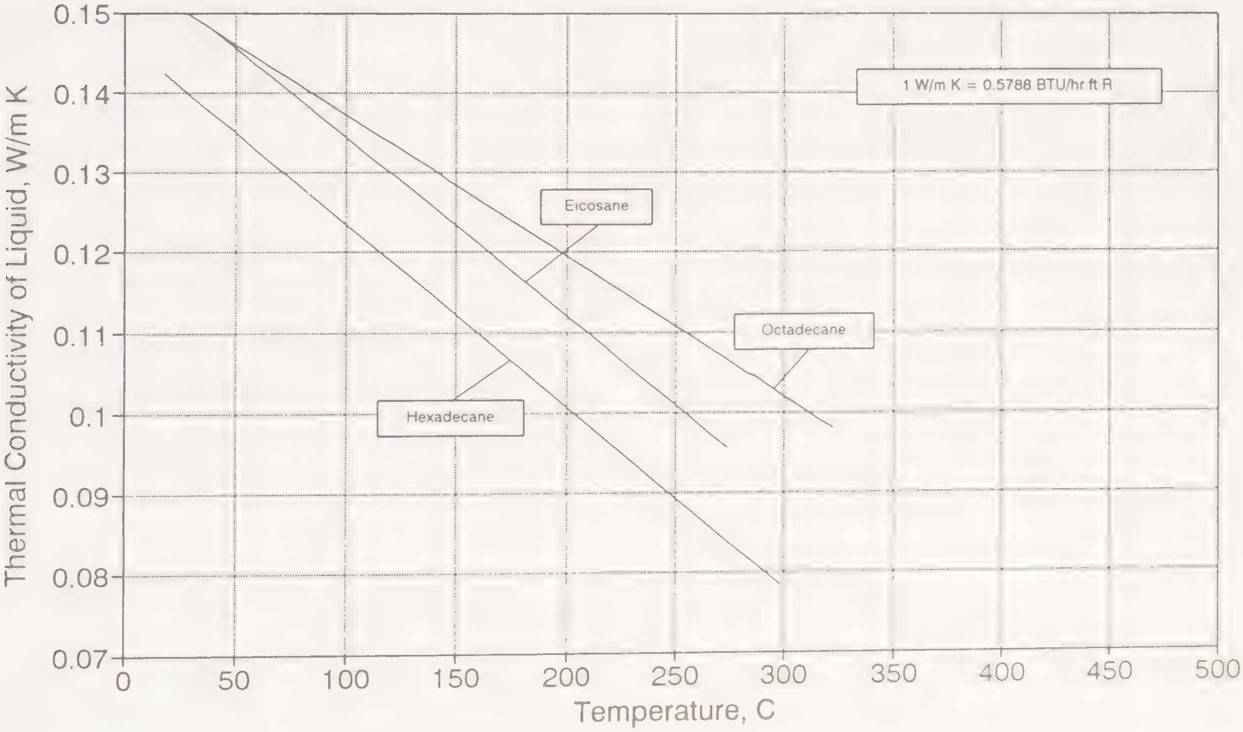

Figure 14-10 Thermal Conductivity of Liquid

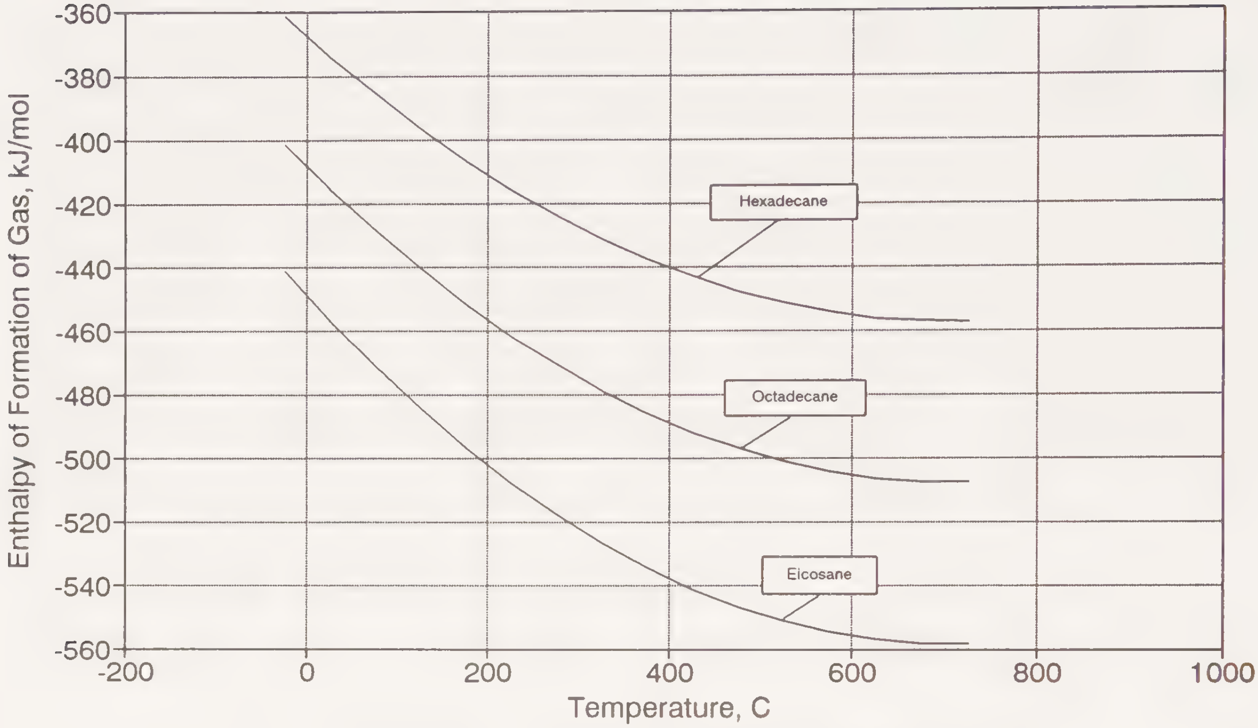

Figure 14-11 Enthalpy of Formation of Gas

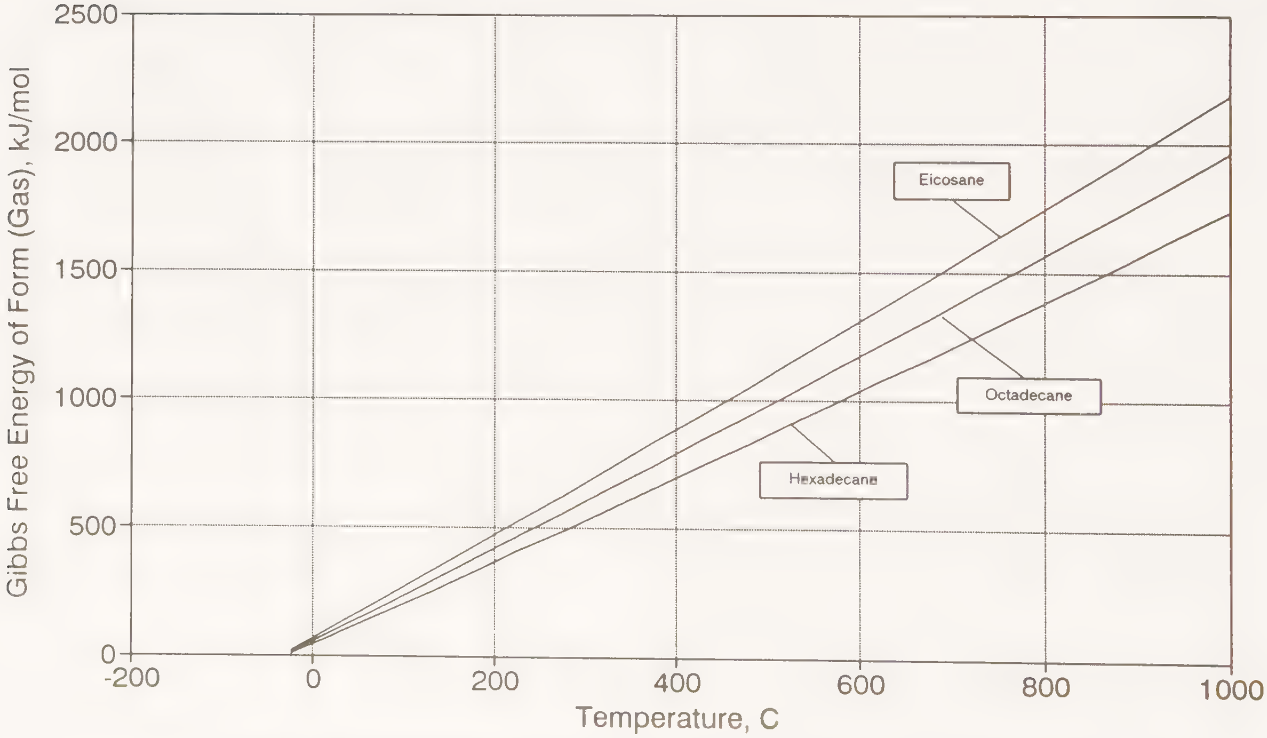

Figure 14-12 Gibbs Free Energy of Formation of Gas

Chapter 15

C_{10}, C_{12} AND C_{14} ALPHA ALKENES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 15-1

Property data from the literature (1-23,25-36,38-59,72-75,95,97,139,158,166,169-172) are given in Table 15-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation and explosion limits in air are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 15-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 15-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 15-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density for all compounds except for 1-decene where more recent data (5) for critical constants was adopted. The range of coverage applies to temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 2% in most cases.

SURFACE TENSION - Figure 15-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 15-5 and 15-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 15-7 and 15-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 15-9 and 15-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

ENTHALPY OF FORMATION - Figure 15-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 15-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 15-1 Physical Properties

1. Name	1-Decene	1-Dodecene	1-Tetradecene
2. Formula	C10H20	C12H24	C14H28
3. Molecular Weight, g/mol	140.269	168.323	196.376
4. Critical Temperature, K	617.05	657.00	692.00
5. Critical Pressure, bar	21.684	18.90	16.60
6. Critical Volume, ml/mol	585.00	700.00	817.00
7. Critical Compressibility Factor	0.247	0.242	0.236
8. Acentric Factor	0.4645	0.5636	0.6482
9. Melting Point, K	206.89	237.93	260.30
10. Boiling Point @ 1 atm, K	443.75	486.50	524.45
11. Heat of Vaporization @ BP, kJ/kg	275.58	255.28	238.87
12. Density of Liquid @ 25 C, g/ml	0.763	0.754	0.769
13. Surface Tension @ 25 C, dynes/cm	23.54	25.15	26.36
14. Heat Capacity of Gas @ 25 C, J/g K	1.594	1.600	1.604
15. Heat Capacity of Liquid @ 25 C, J/g K	2.117	2.138	2.197
16. Viscosity of Gas @ 25 C, micropoise	53.01	49.02	45.73
17. Viscosity of Liquid @ 25 C, centipoise	0.762	1.210	1.841
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1303	0.1366	0.1394
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-124.35	-165.62	-206.85
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	120.38	137.10	153.83
22. Flash Point, K	326.48	322.04	383.15
23. Autoignition Temperature, K	508.15	528.15	508.15
24. Lower Explosion Limit in Air, vol %	0.7	0.6	0.5
25. Upper Explosion Limit in Air, vol %	5.9	5.4	5.4
26. Solubility in Water @ 25 C, ppm(wt)	------	------	------

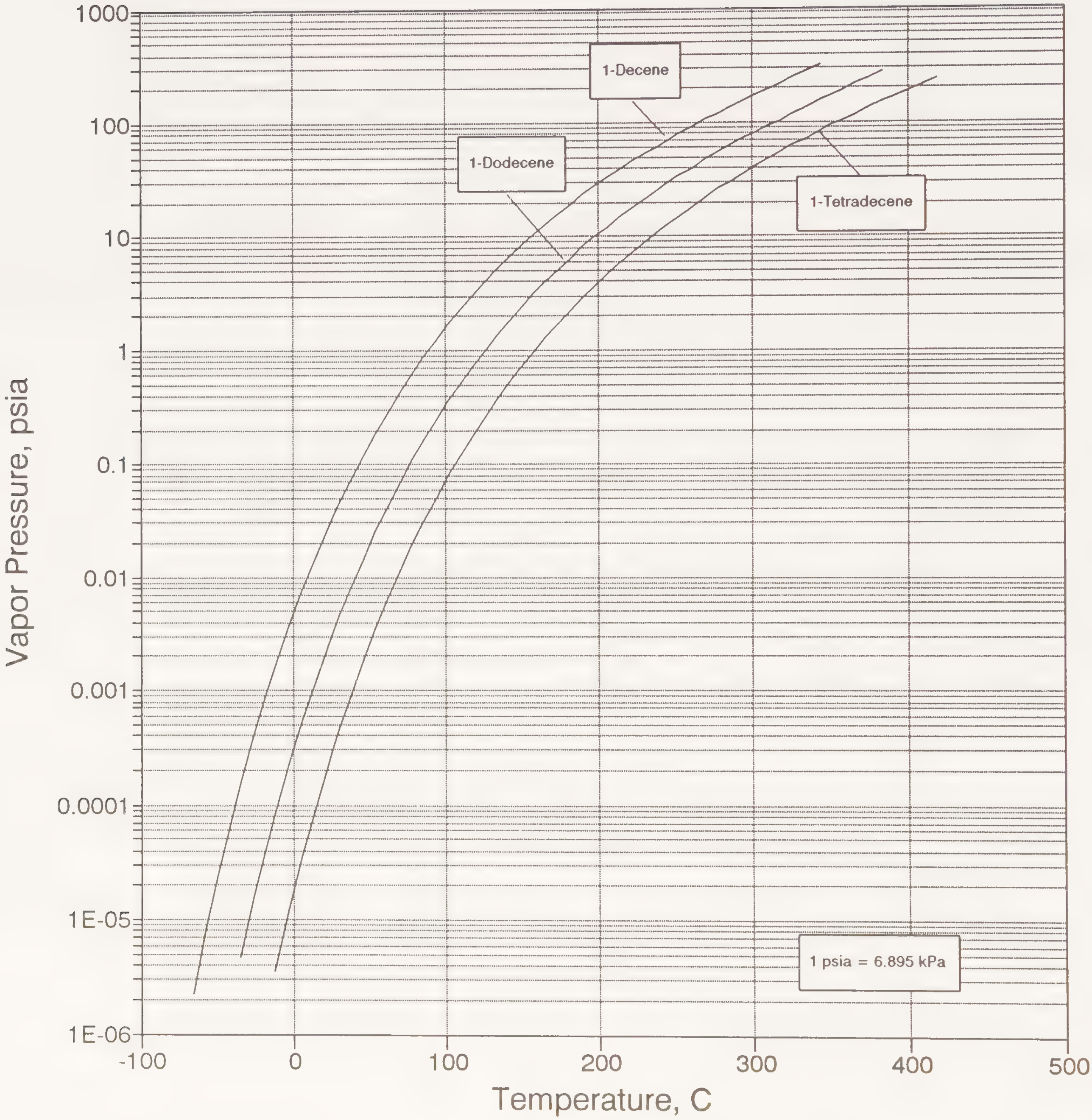

Figure 15-1 Vapor Pressure

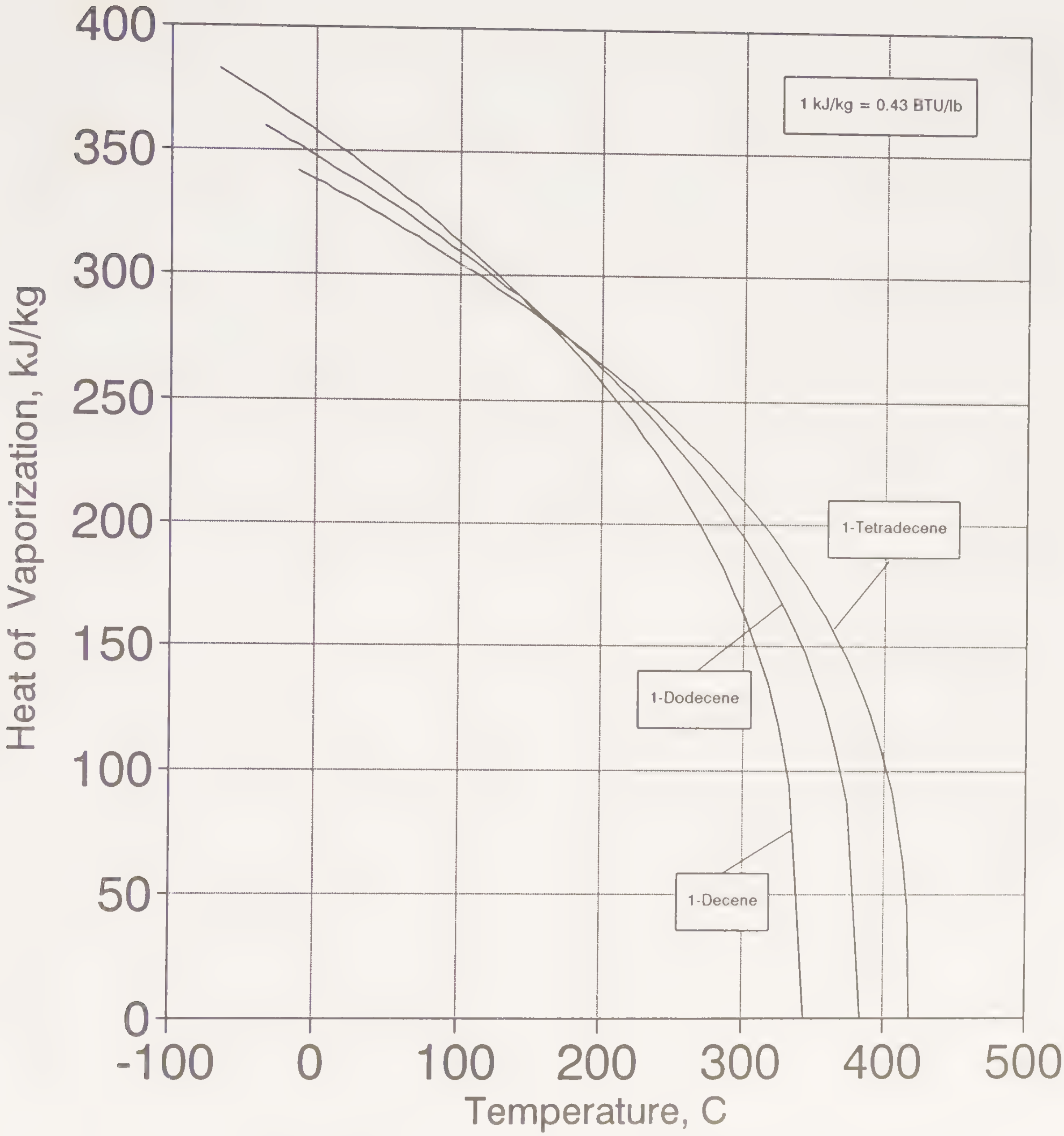

Figure 15-2 Heat of Vaporization

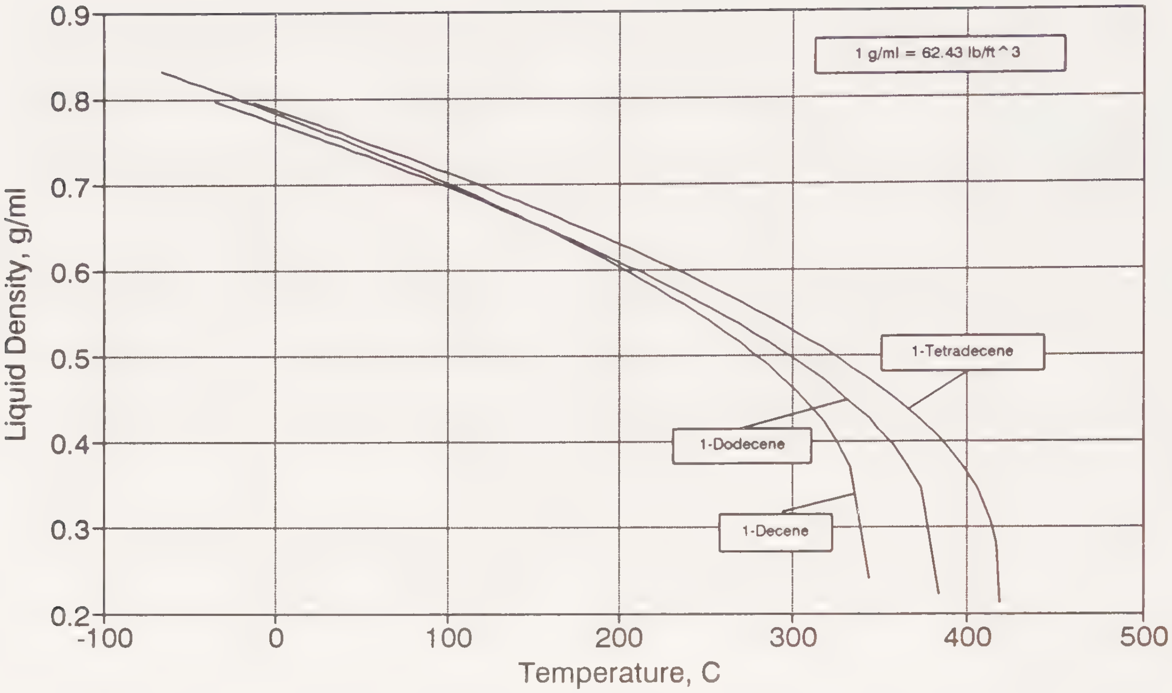

Figure 15-3 Liquid Density

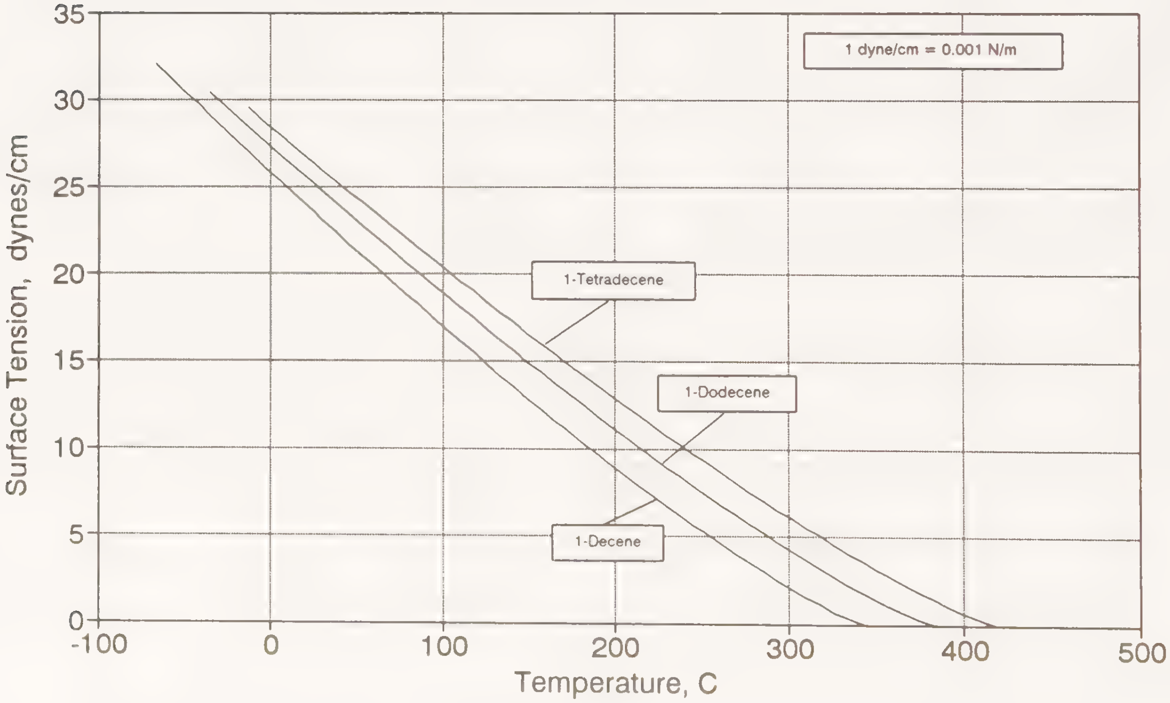

Figure 15-4 Surface Tension

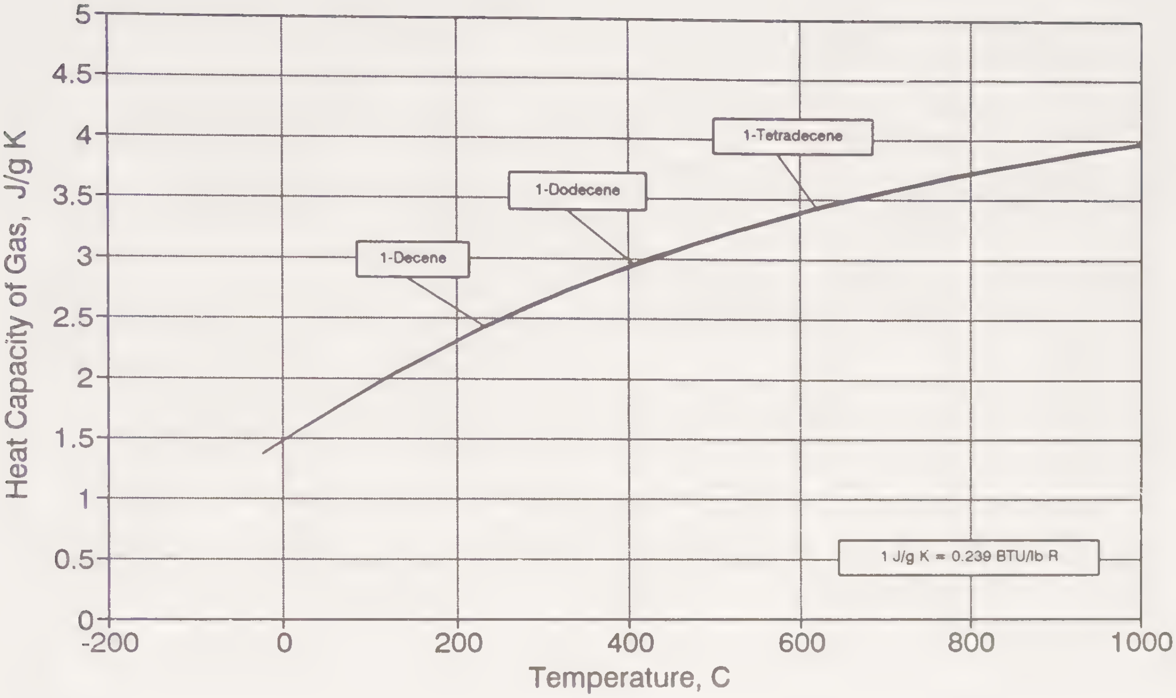

Figure 15-5 Heat Capacity of Gas

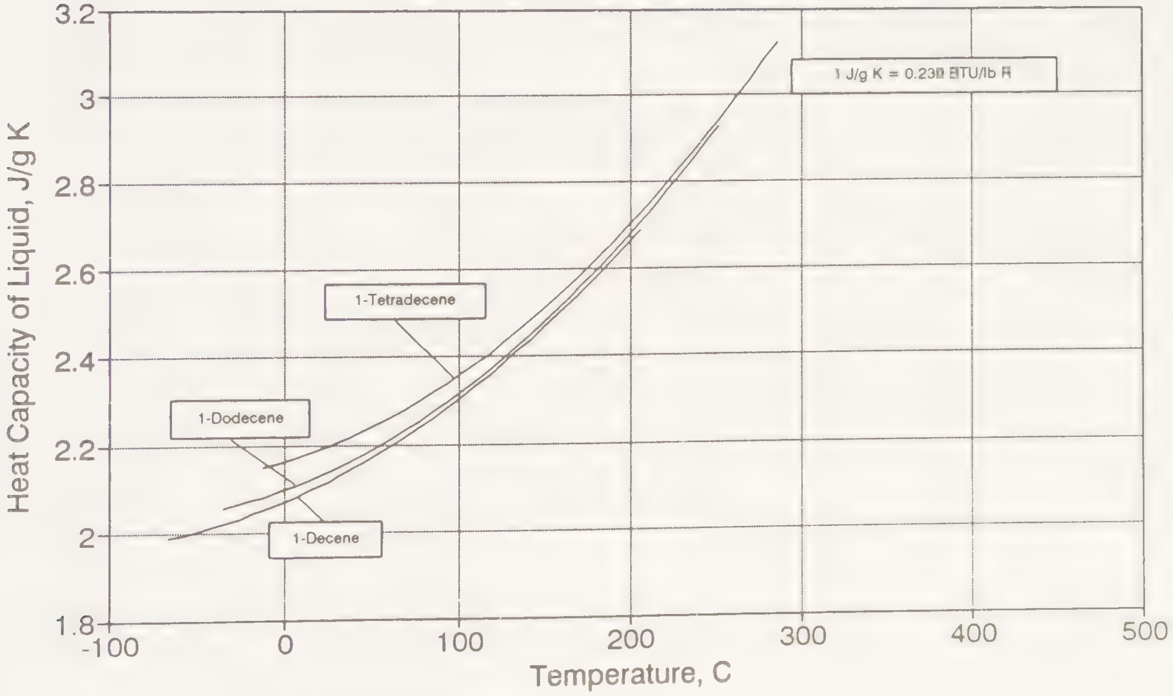

Figure 15-6 Heat Capacity of Liquid

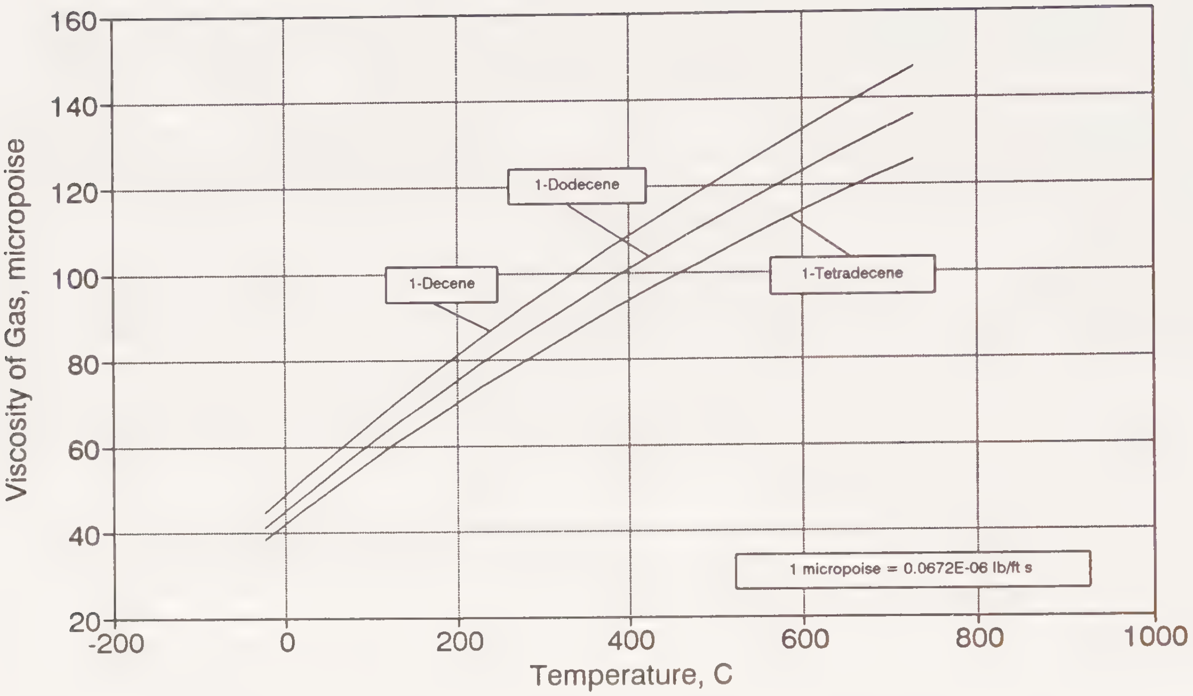

Figure 15-7 Viscosity of Gas

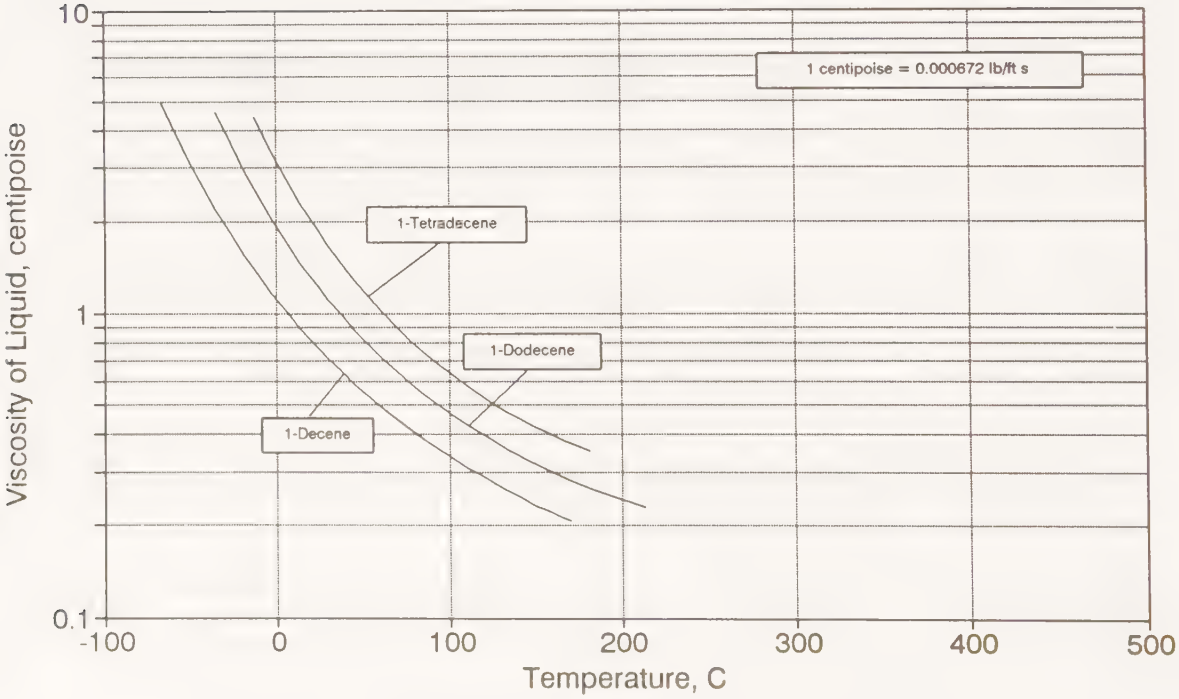

Figure 15-8 Viscosity of Liquid

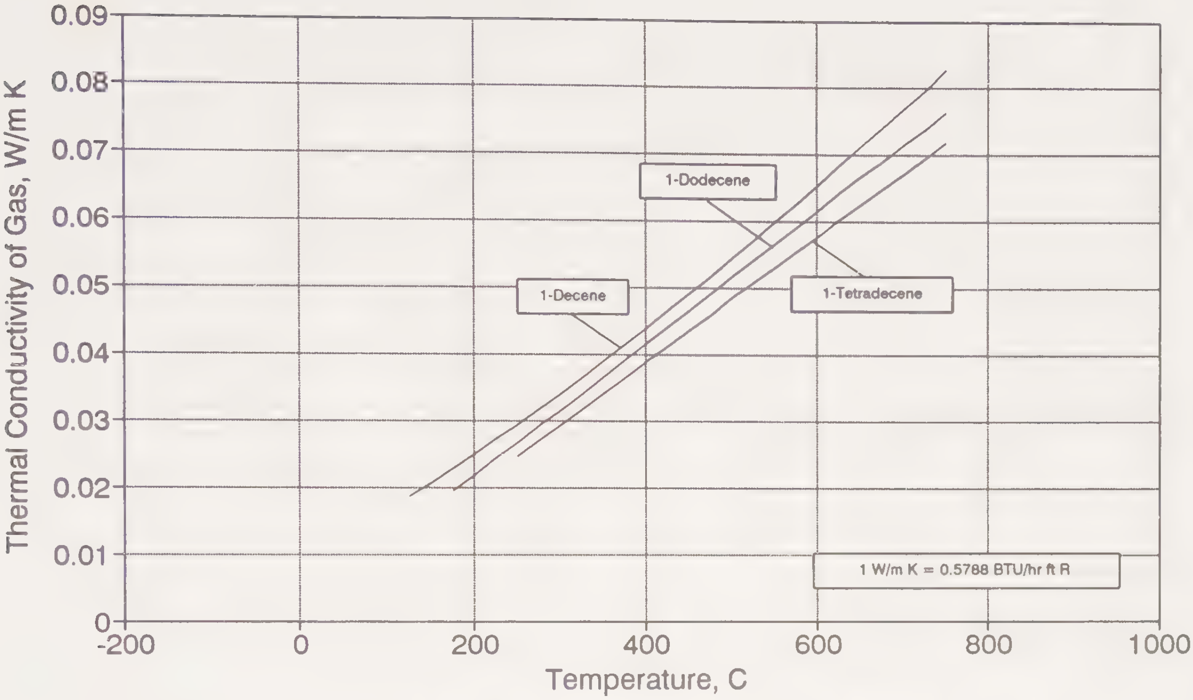

Figure 15-9 Thermal Conductivity of Gas

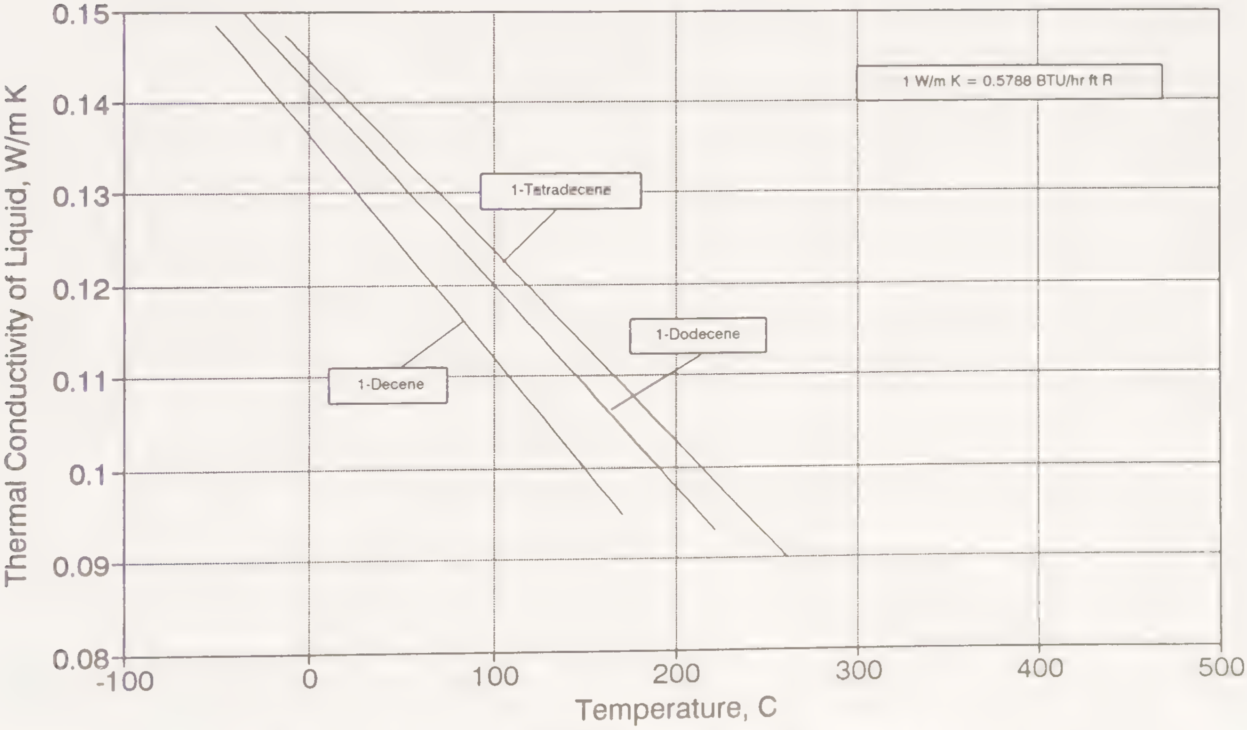

Figure 15-10 Thermal Conductivity of Liquid

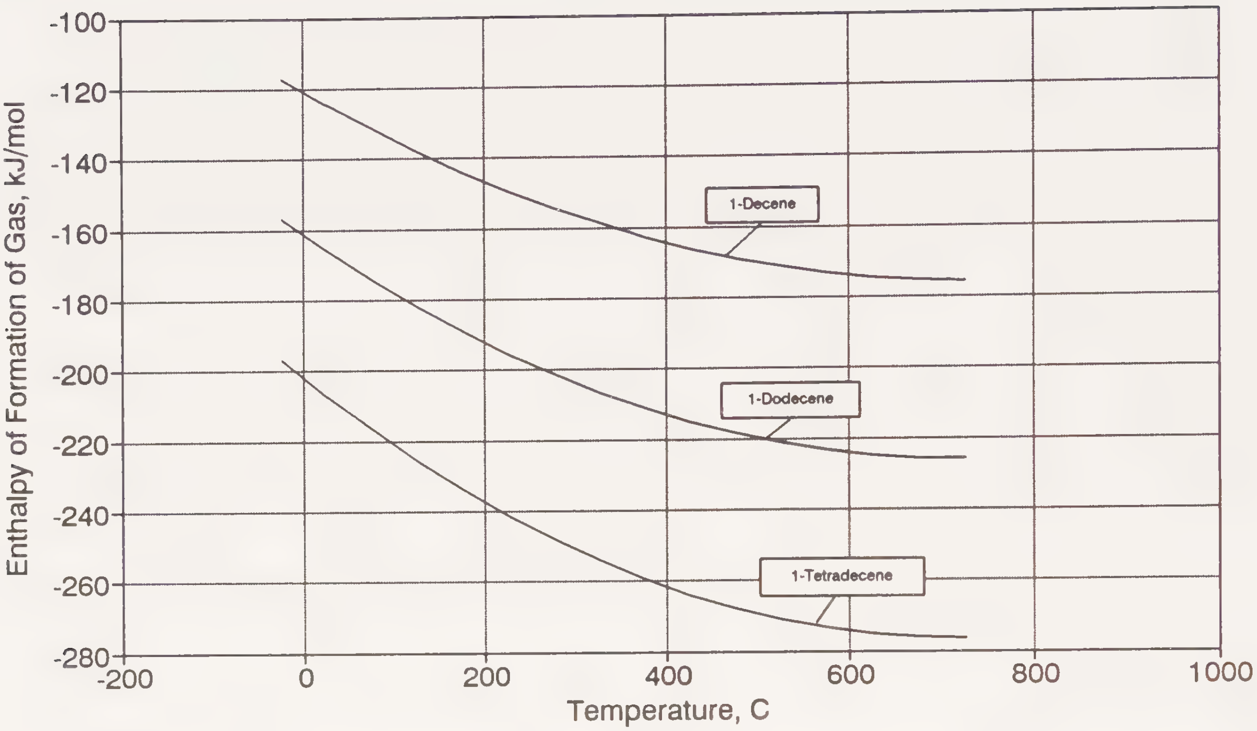

Figure 15-11 Enthalpy of Formation of Gas

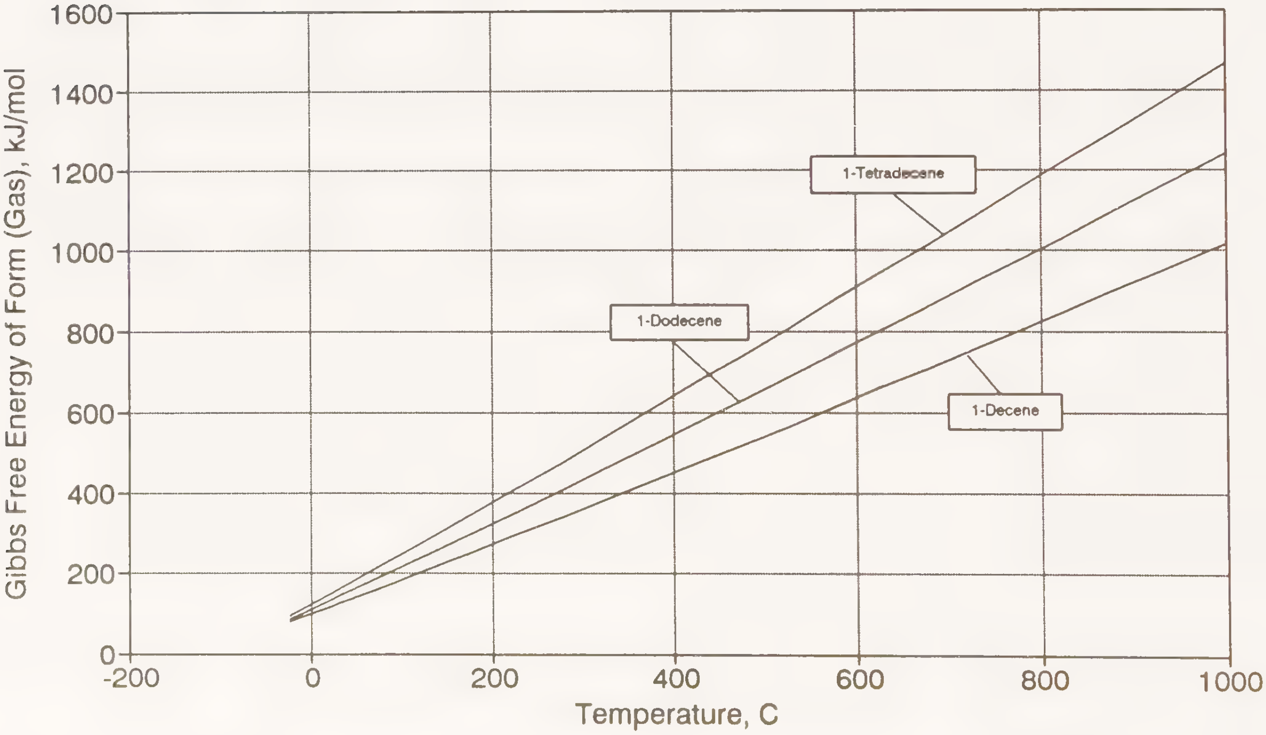

Figure 15-12 Gibbs Free Energy of Formation of Gas

Chapter 16

C_{16}, C_{18} AND C_{20} ALPHA ALKENES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 16-1

Property data from the literature (1-23,25-36,38-59,72-75,95,97,139,158,170) are given in Table 16-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation and explosion limits in air are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 16-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 16-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 10% or less.

LIQUID DENSITY - Figure 16-3

Results from the DIPPR project (5) were selected for liquid density for all compounds except for 1-decene where more recent data (5) for critical constants was adopted. The range of coverage applies to temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 1% in most cases.

SURFACE TENSION - Figure 16-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 16-5 and 16-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. The curve for 1-eicosene was adjusted to make it similar in shape to the curves for 1-hexadecene and 1-octadecene. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 16-7 and 16-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 16-9 and 16-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 16-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 16-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 16-1 Physical Properties

1. Name	1-Hexadecene	1-Octadecene	1-Eicosene
2. Formula	C16H32	C18H36	C20H40
3. Molecular Weight, g/mol	224.430	252.484	280.538
4. Critical Temperature, K	722.00	748.00	771.00
5. Critical Pressure, bar	14.80	13.40	12.20
6. Critical Volume, ml/mol	933.0	1050.0	1160.0
7. Critical Compressibility Factor	0.230	0.226	0.221
8. Acentric Factor	0.7319	0.7901	0.8768
9. Melting Point, K	277.51	290.76	301.76
10. Boiling Point @ 1 atm, K	558.02	587.97	615.54
11. Heat of Vaporization @ BP, kJ/kg	224.63	214.94	199.54
12. Density of Liquid @ 25 C, g/ml	0.777	0.785	0.789 @ 28.6 C
13. Surface Tension @ 25 C, dynes/cm	27.32	28.06	28.27 @ 28.6 C
14. Heat Capacity of Gas @ 25 C, J/g K	1.608	1.610	1.612
15. Heat Capacity of Liquid @ 25 C, J/g K	2.167	2.154	2.109 @ 28.6 C
16. Viscosity of Gas @ 25 C, micropoise	43.19	41.06	39.30
17. Viscosity of Liquid @ 25 C, centipoise	2.711	3.535	4.665 @ 28.6 C
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1420	0.1437	0.1446 @ 28.6 C
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-248.19	-289.46	-330.72
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	170.44	187.14	203.83
22. Flash Point, K	397.00	419.00	439.00
23. Autoignition Temperature, K	513.15	523.15	510.00
24. Lower Explosion Limit in Air, vol %	0.5	0.4	0.4
25. Upper Explosion Limit in Air, vol %	------	------	------
26. Solubility in Water @ 25 C, ppm(wt)	------	------	------

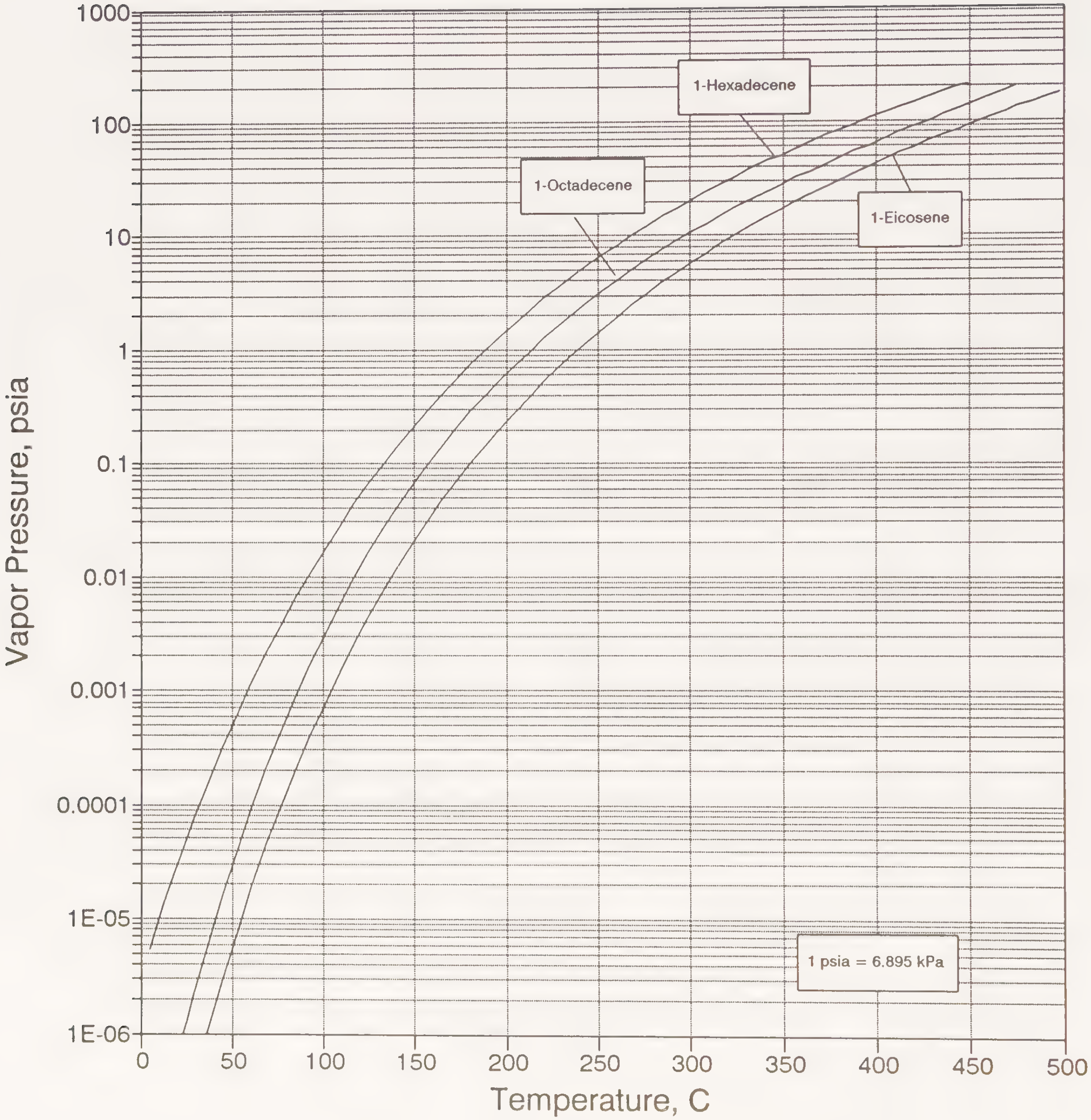

Figure 16-1 Vapor Pressure

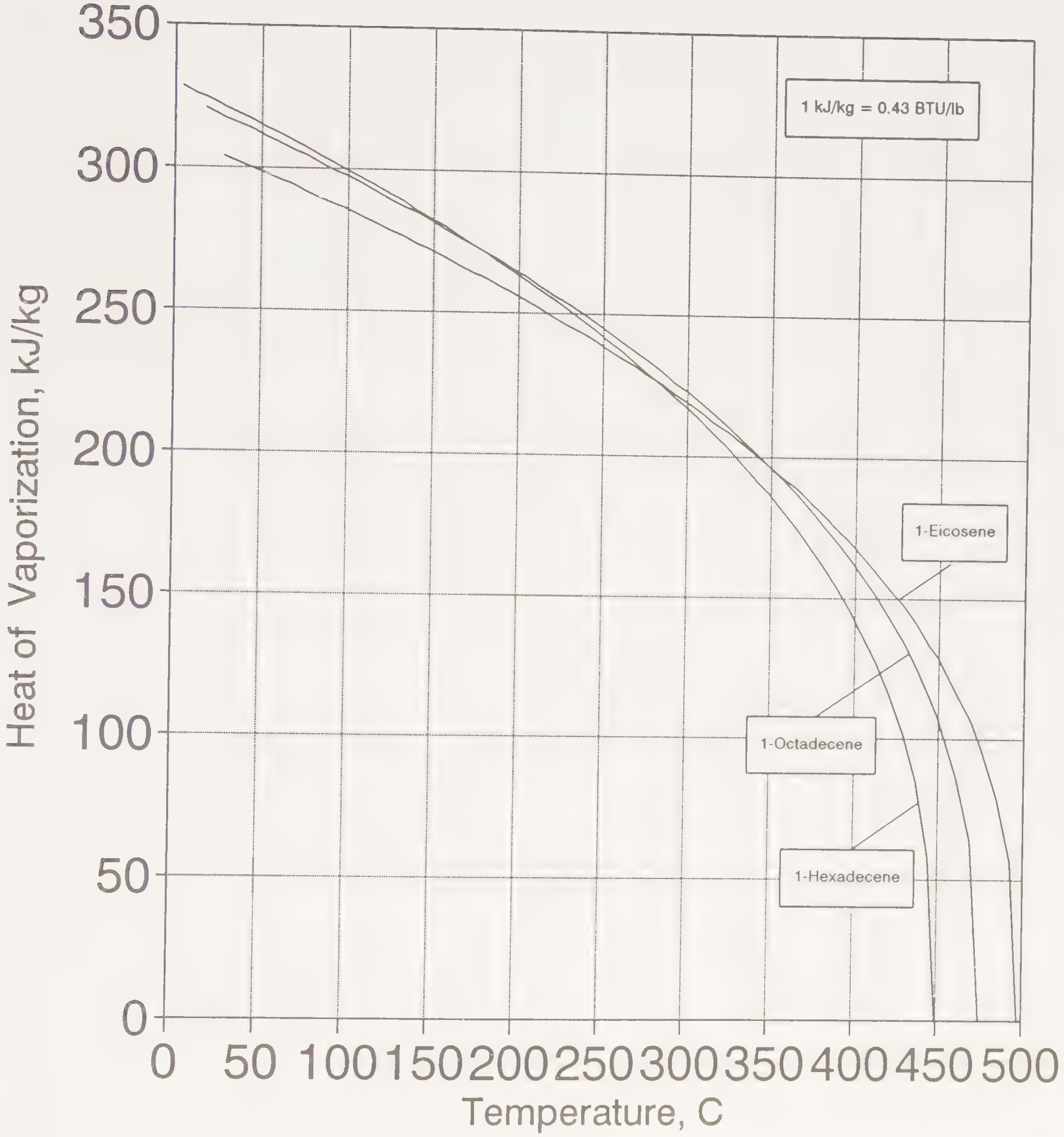

Figure 16-2 Heat of Vaporization

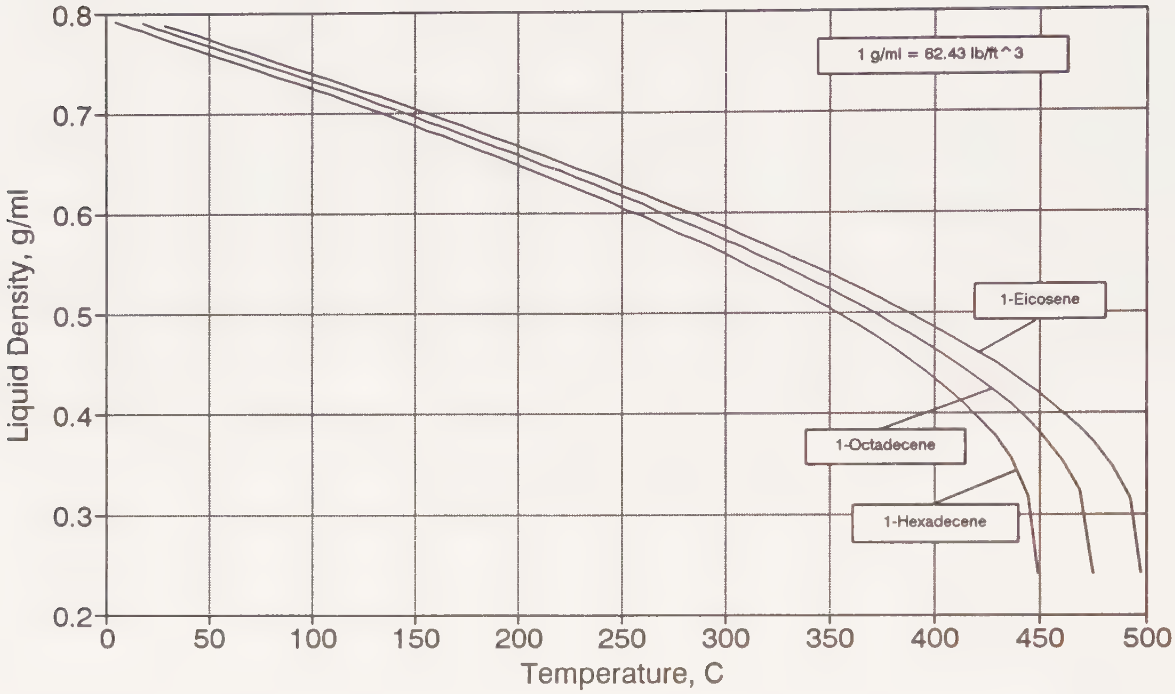

Figure 16-3 Liquid Density

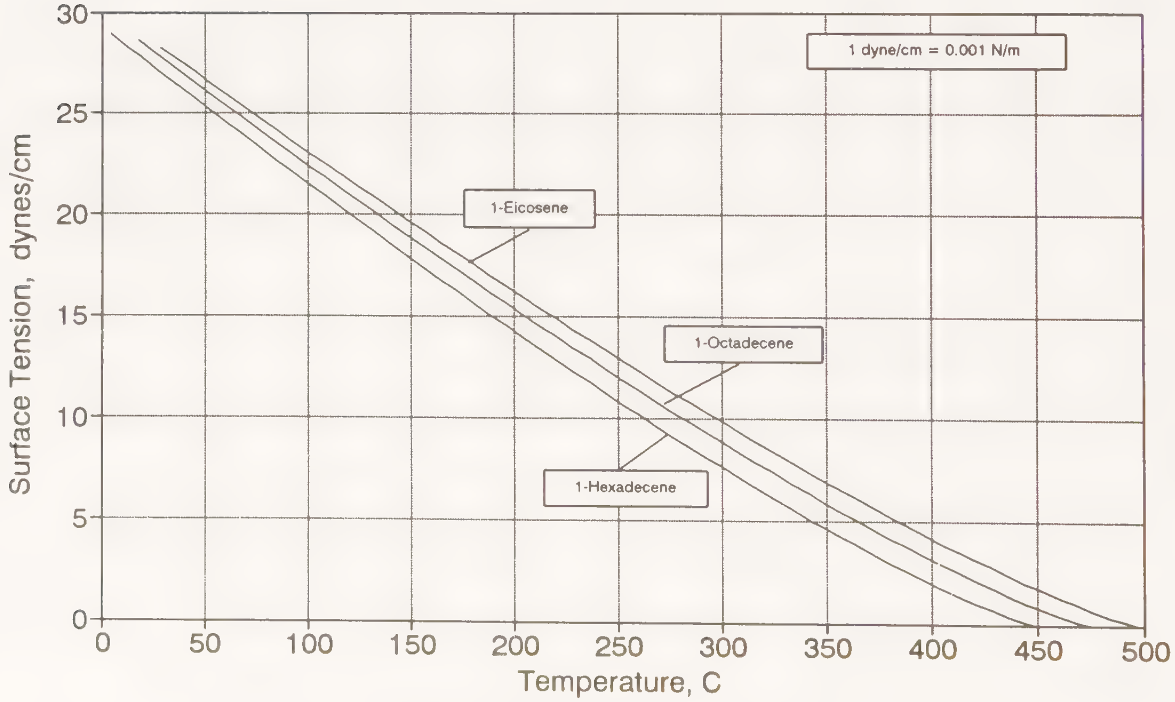

Figure 16-4 Surface Tension

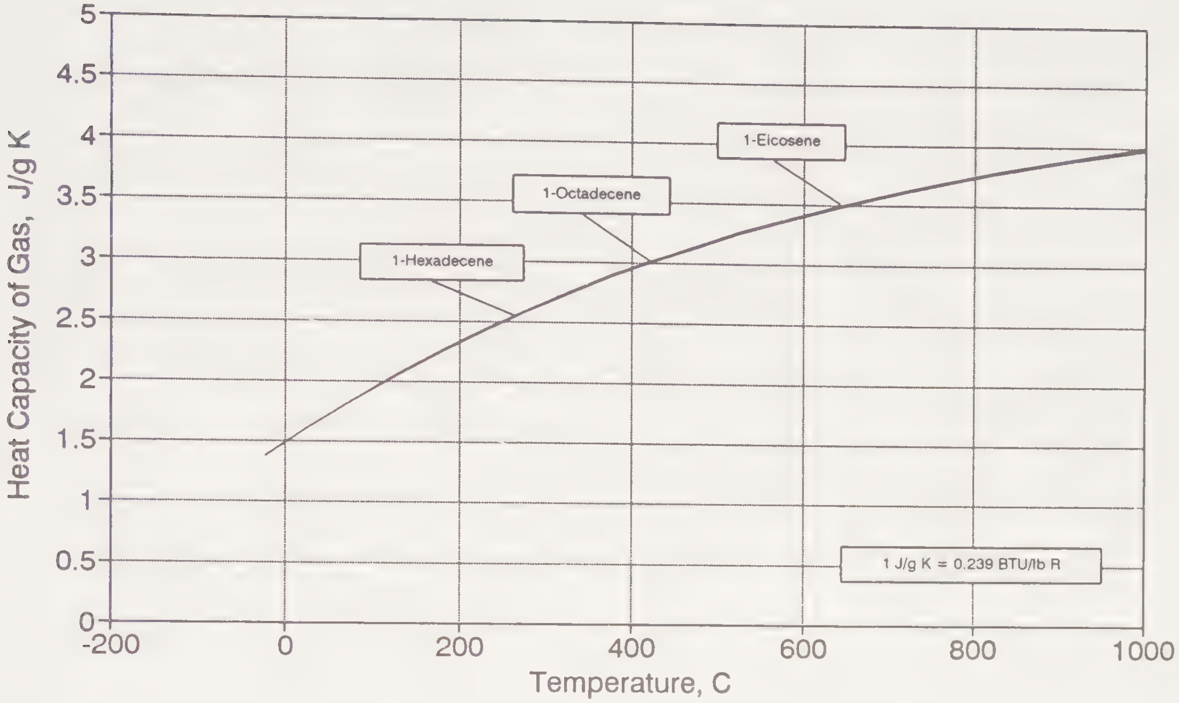

Figure 16-5 Heat Capacity of Gas

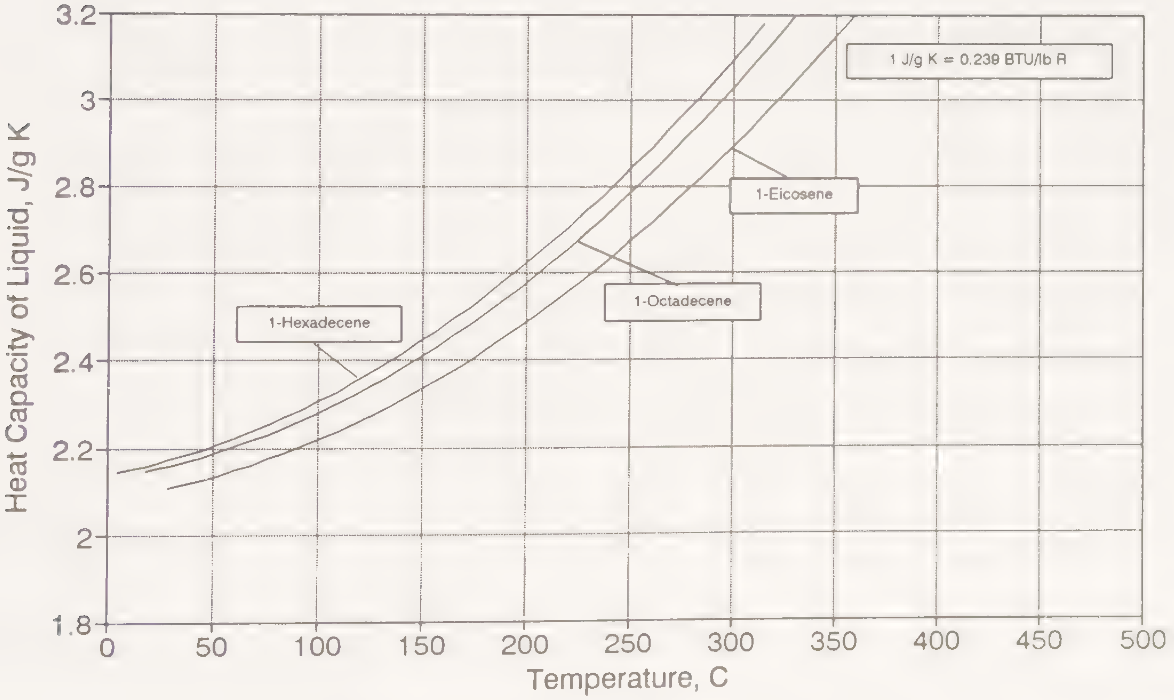

Figure 16-6 Heat Capacity of Liquid

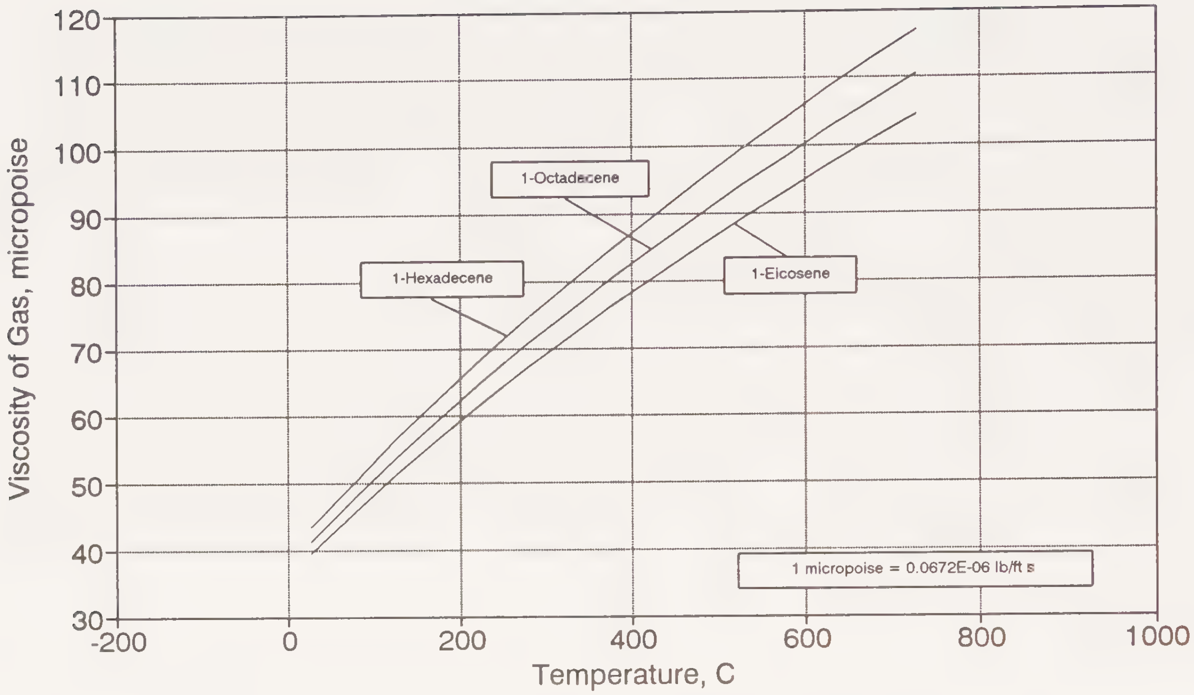

Figure 16-7 Viscosity of Gas

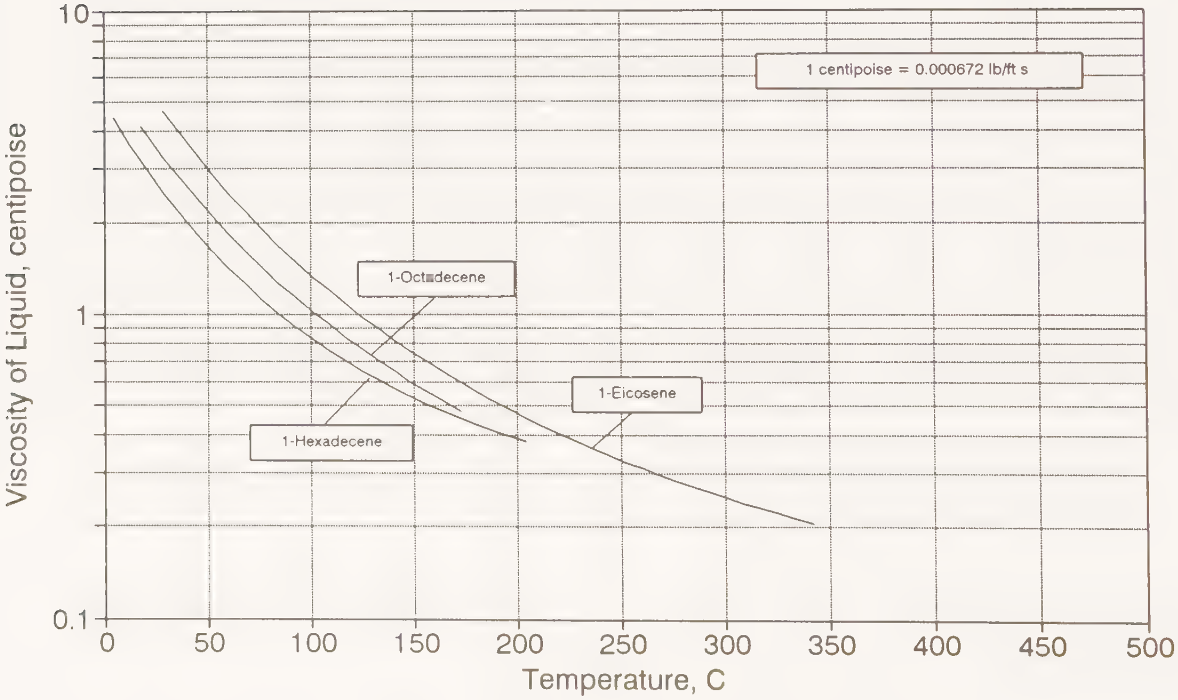

Figure 16-8 Viscosity of Liquid

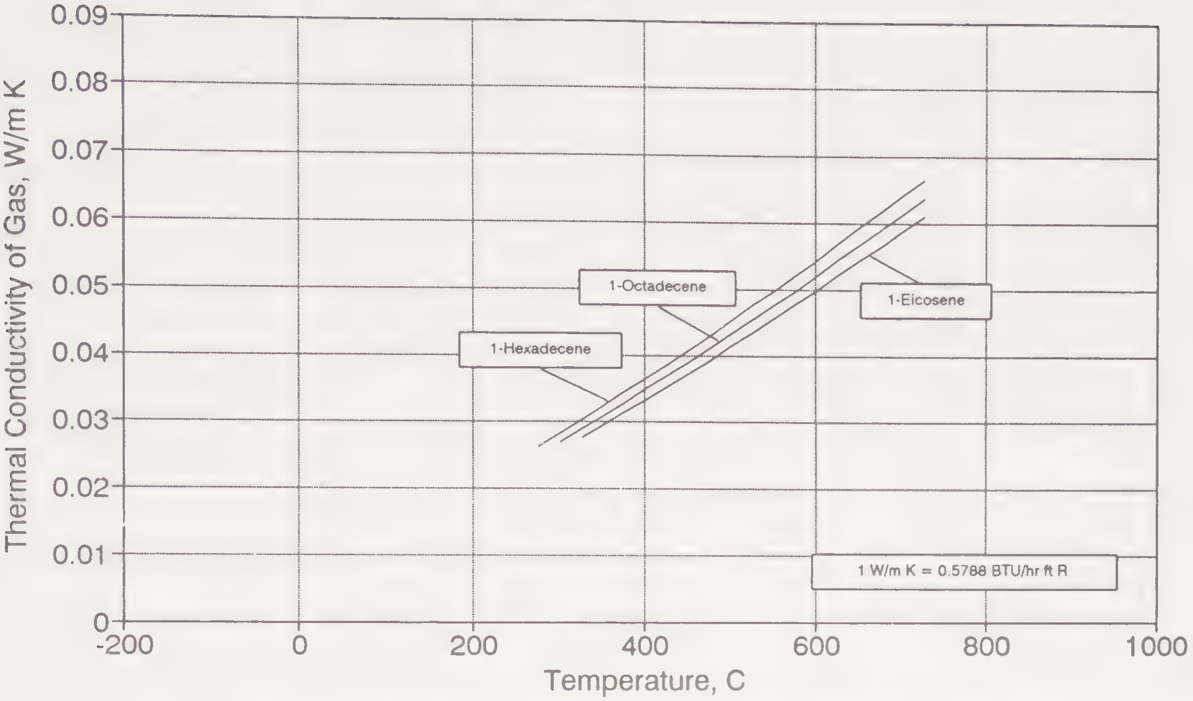

Figure 16-9 Thermal Conductivity of Gas

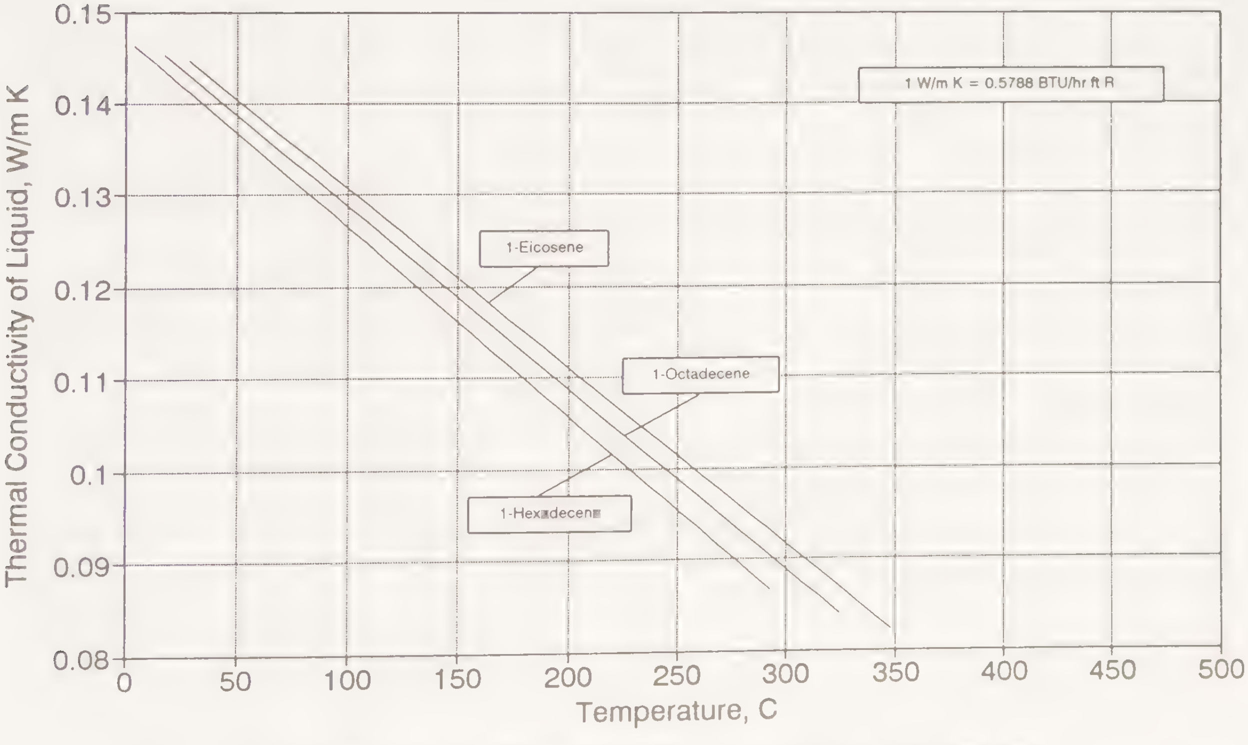

Figure 16-10 Thermal Conductivity of Liquid

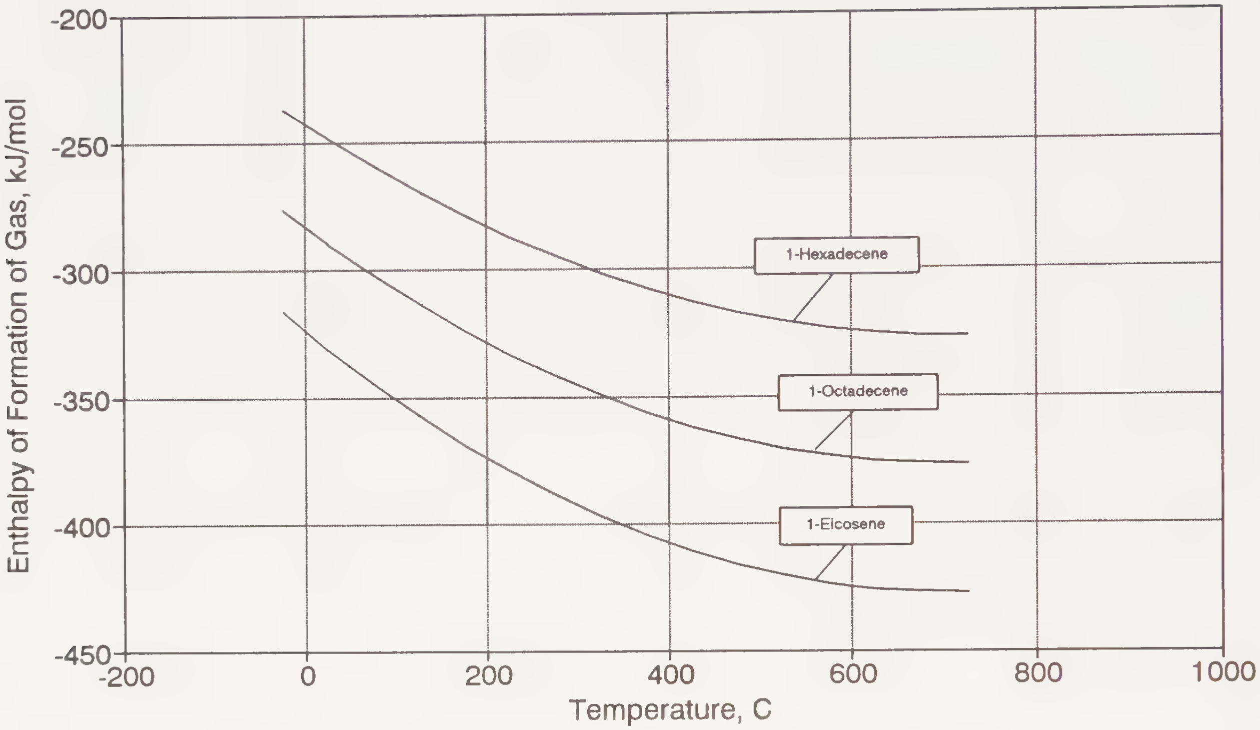

Figure 16-11 Enthalpy of Formation of Gas

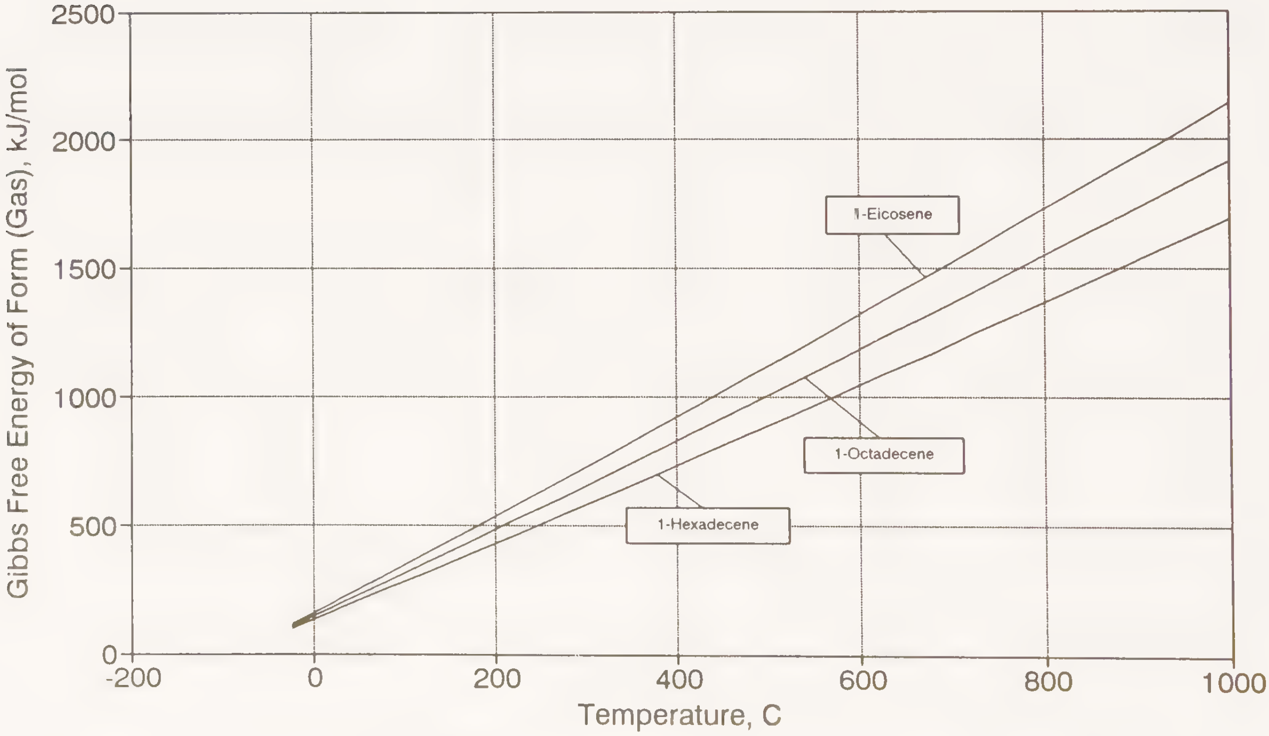

Figure 16-12 Gibbs Free Energy of Formation of Gas

Chapter 17

C_1 TO C_3 NORMAL ALKYL CYCLOPENTANES

Robert W. Gallant, Carl L. Yaws and Xiaoyan Lin

PHYSICAL PROPERTIES - Table 17-1

Property data from the literature (1-23,25-36,38-59,75,85,95-97,139,164-166,173-177) are given in Table 17-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation, lower explosion limit in air and solubility in water are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 17-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 17-2

Results from the DIPPR project (5) were selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2a), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 17-3

Results from the DIPPR project (5) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 17-4

Results from the DIPPR project (5) were selected for liquid surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4a). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 17-5 and 17-6

Results from the DIPPR project (5) were selected for heat capacity of ideal gas. Correlation of data was accomplished using Equation (1-5b). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 1% or less using the correlation.

VISCOSITY - Figures 17-7 and 17-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 17-9 and 17-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 17-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 17-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 17-1 Physical Properties

1. Name	Methyl-cyclopentane	Ethyl-cyclopentane	Propyl-cyclopentane
2. Formula	C6H12	C7H14	C8H16
3. Molecular Weight, g/mol	84.161	98.188	112.215
4. Critical Temperature, K	532.79	569.52	603.00
5. Critical Pressure, bar	37.845	33.977	30.000
6. Critical Volume, ml/mol	318.92	374.52	425.00
7. Critical Compressibility Factor	0.272	0.269	0.254
8. Acentric Factor	0.2302	0.2715	0.2719
9. Melting Point, K	130.73	134.71	155.82
10. Boiling Point @ 1 atm, K	344.96	376.62	404.11
11. Heat of Vaporization @ BP, kJ/kg	348.59	328.41	308.28
12. Density of Liquid @ 25 C, g/ml	0.745	0.763	0.773
13. Surface Tension @ 25 C, dynes/cm	21.65	23.33	24.42
14. Heat Capacity of Gas @ 25 C, J/g K	1.298	1.338	1.377
15. Heat Capacity of Liquid @ 25 C, J/g K	1.885	1.896	1.928
16. Viscosity of Gas @ 25 C, micropoise	------	------	------
17. Viscosity of Liquid @ 25 C, centipoise	0.477	0.535	0.640
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1186	0.1169	0.1149
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-106.89	-127.26	-148.31
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	35.25	44.00	51.95
22. Flash Point, K	245.93	269.00	289.00
23. Autoignition Temperature, K	602.04	533.15	542.15
24. Lower Explosion Limit in Air, vol %	1.2	1.1	0.9
25. Upper Explosion Limit in Air, vol %	8.4	6.7	6.4
26. Solubility in Water @ 25 C, ppm(wt)	42.64	9.556	2.04

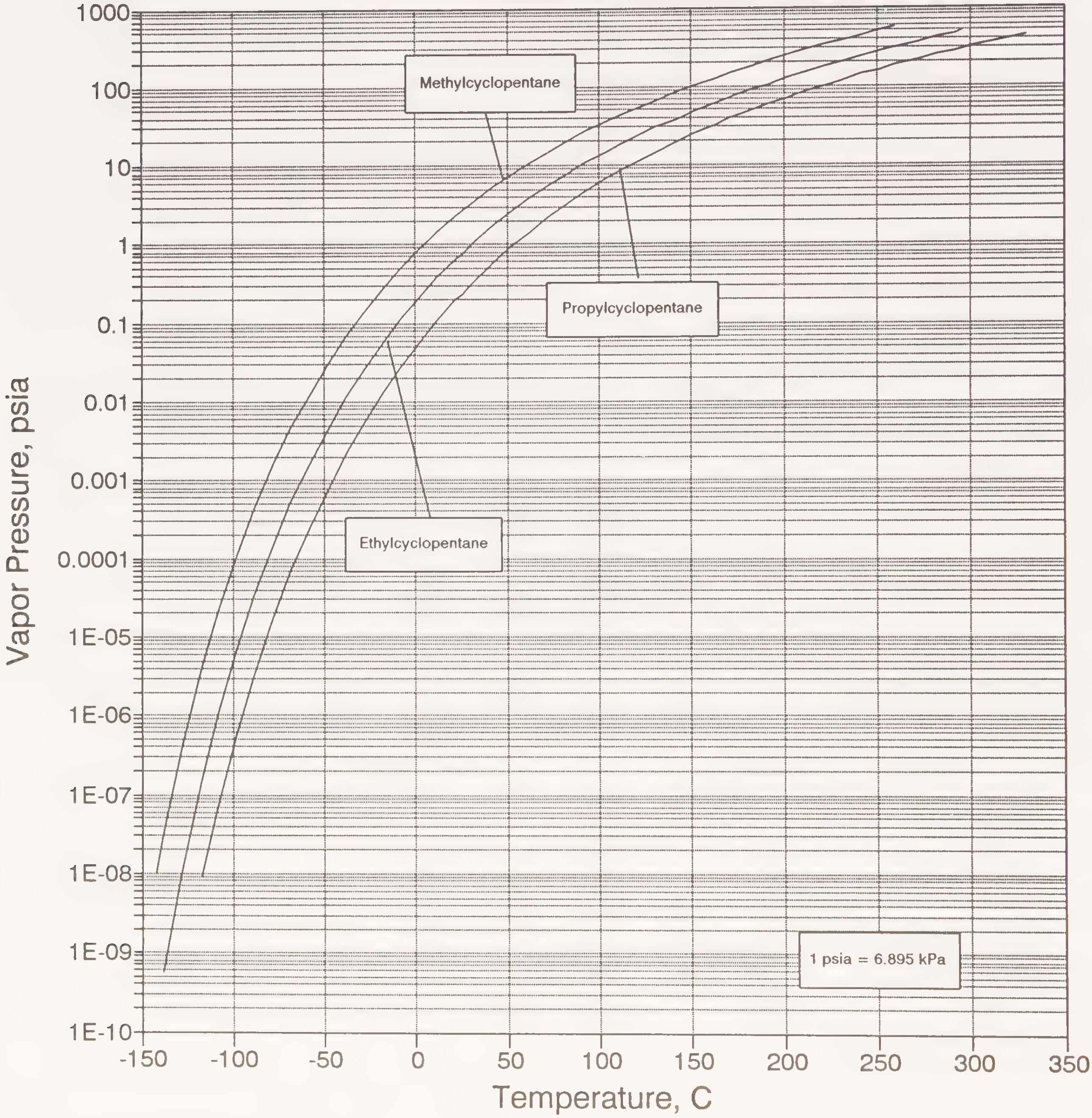

Figure 17-1 Vapor Pressure

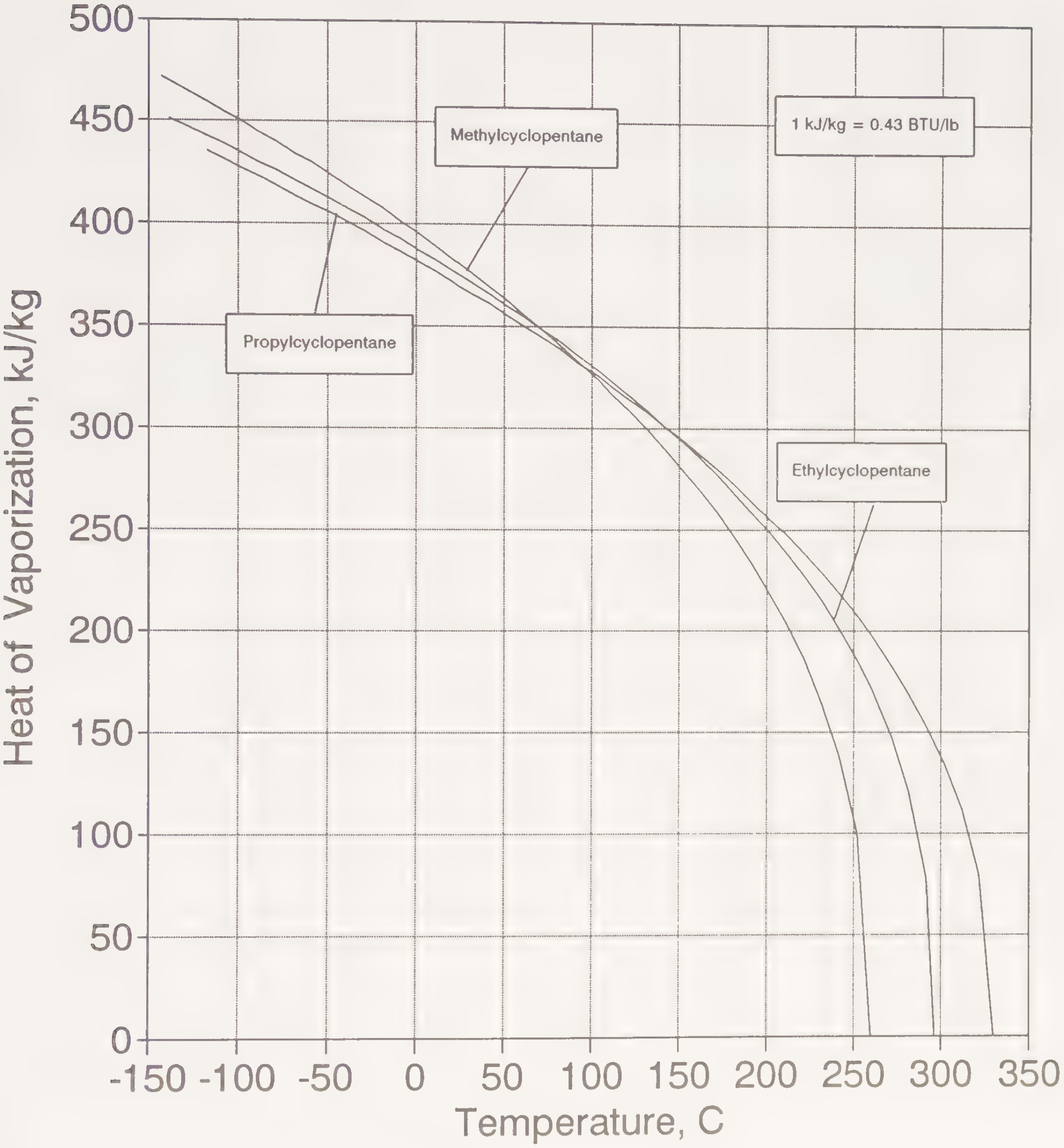

Figure 17-2 Heat of Vaporization

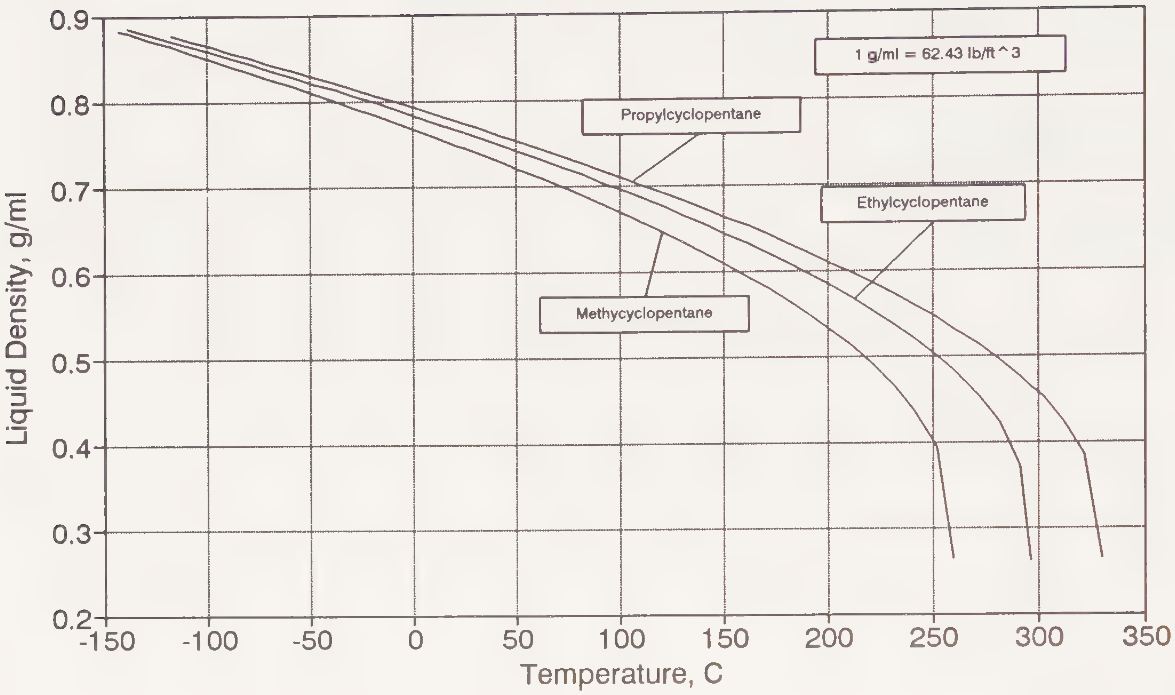

Figure 17-3 Liquid Density

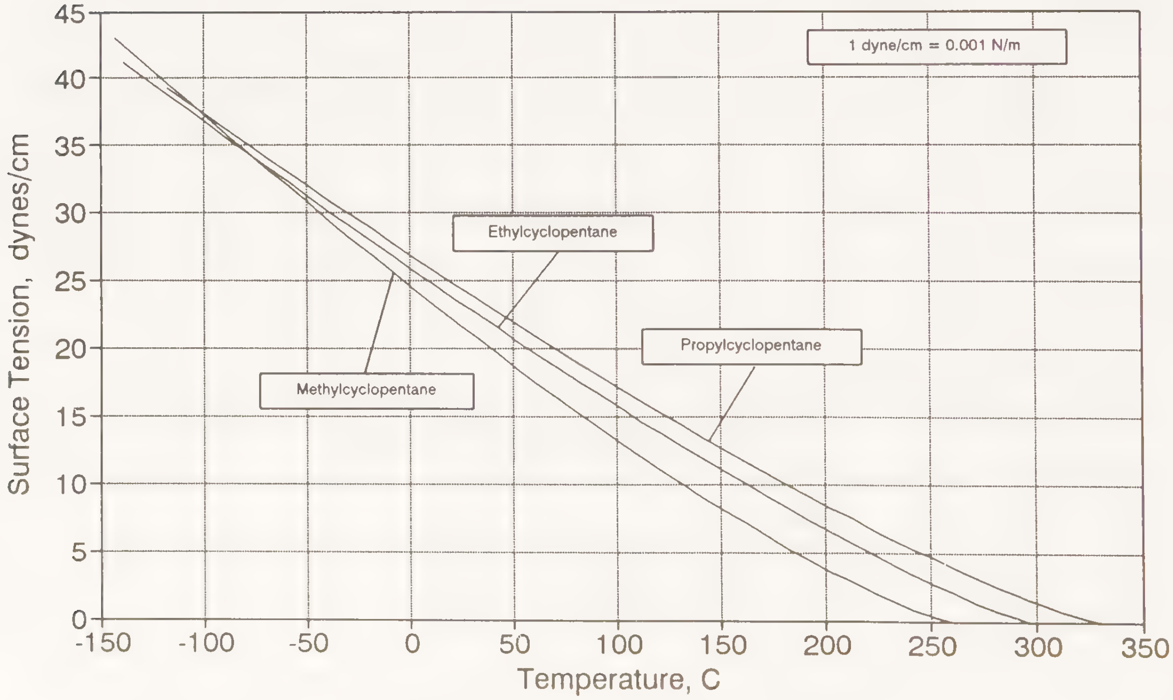

Figure 17-4 Surface Tension

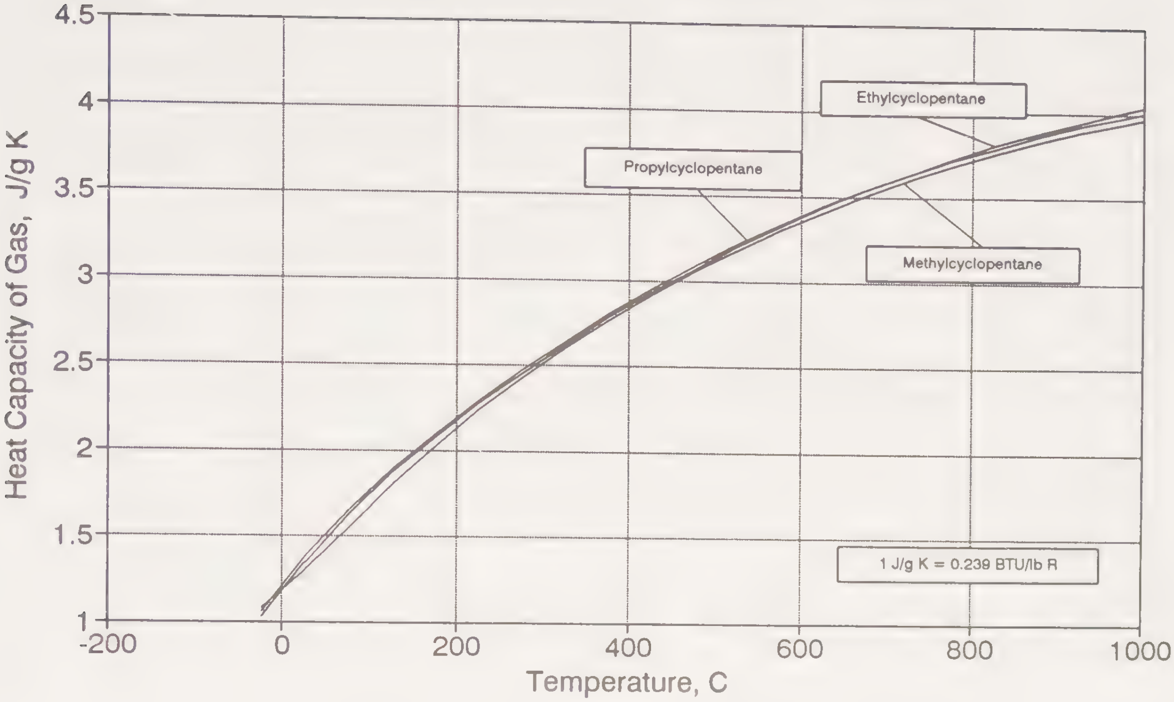

Figure 17-5 Heat Capacity of Gas

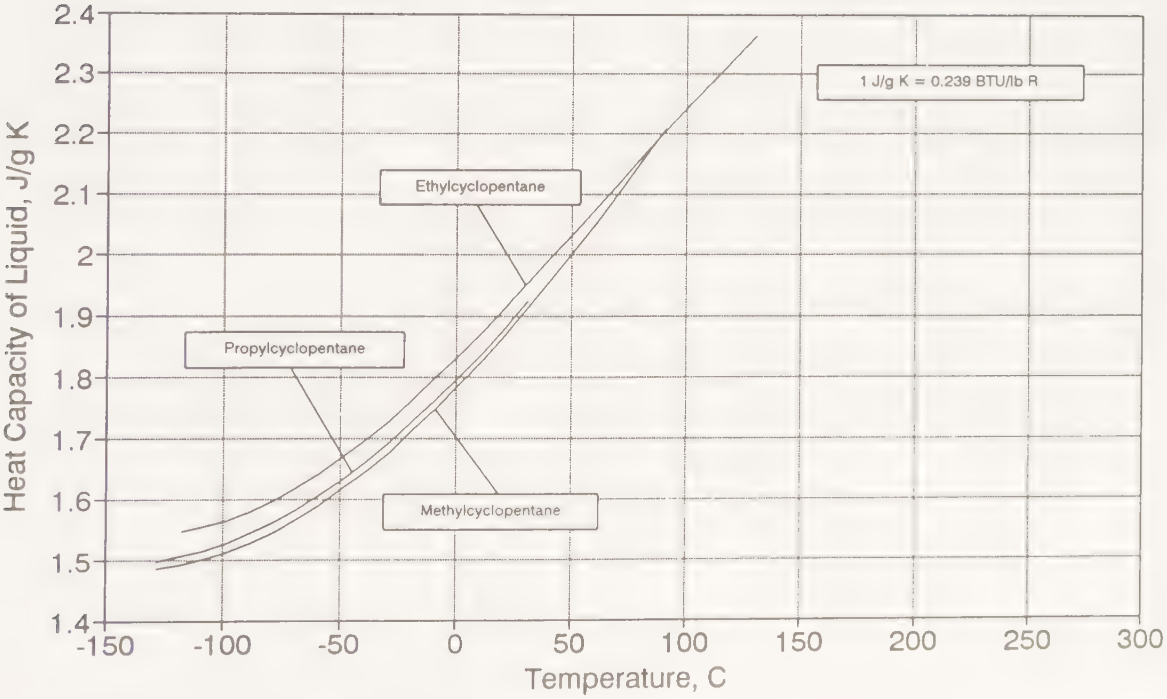

Figure 17-6 Heat Capacity of Liquid

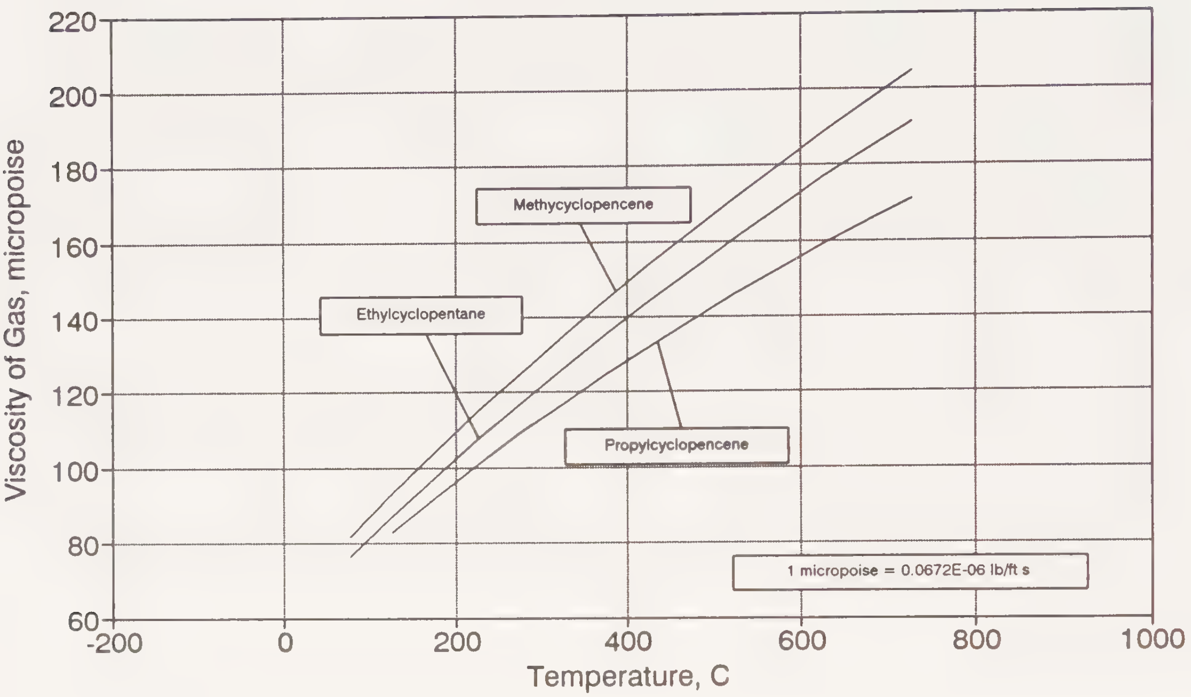

Figure 17-7 Viscosity of Gas

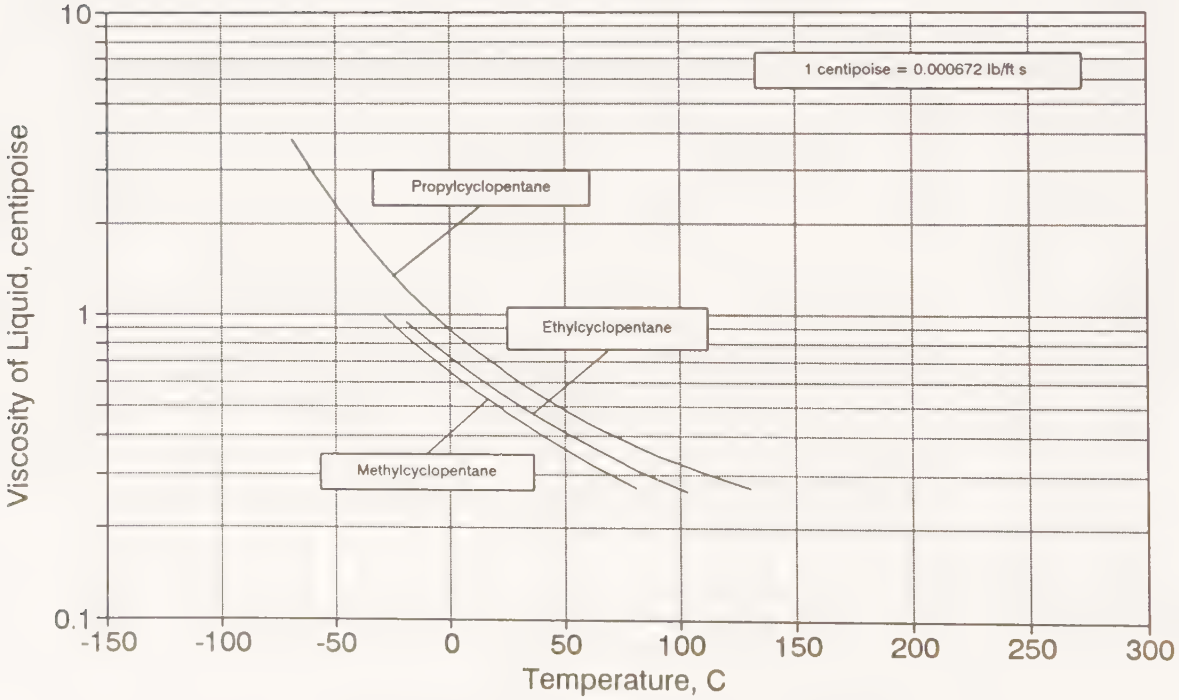

Figure 17-8 Viscosity of Liquid

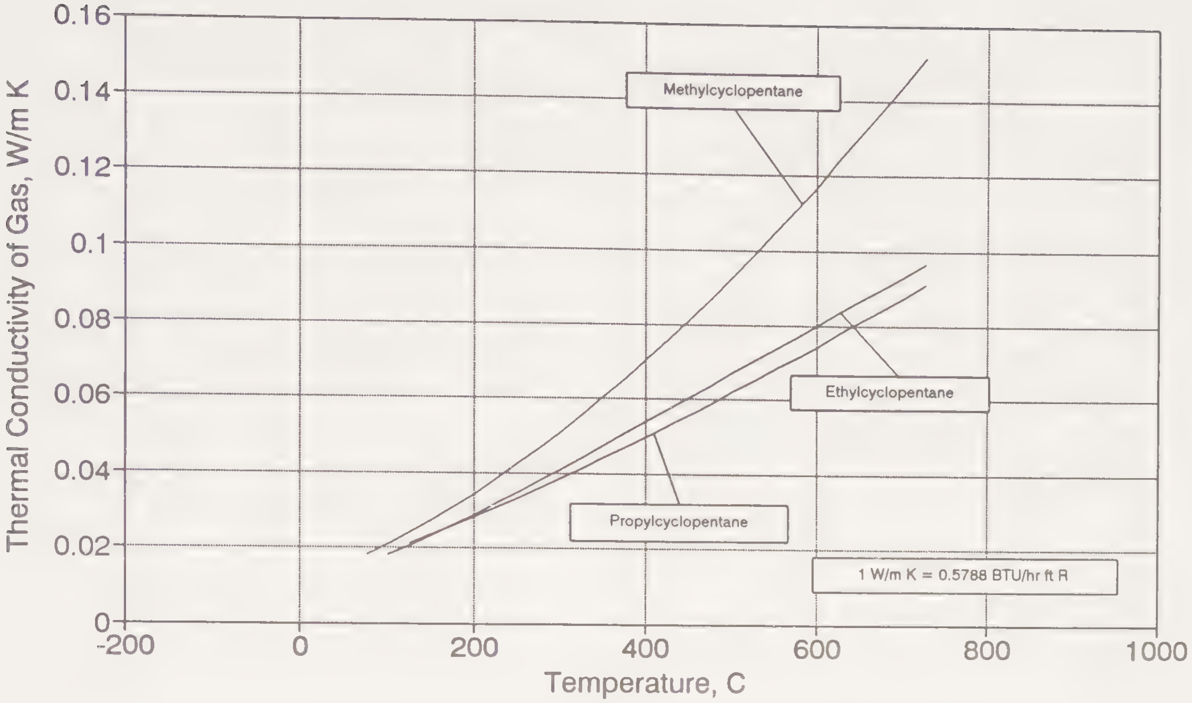

Figure 17-9 Thermal Conductivity of Gas

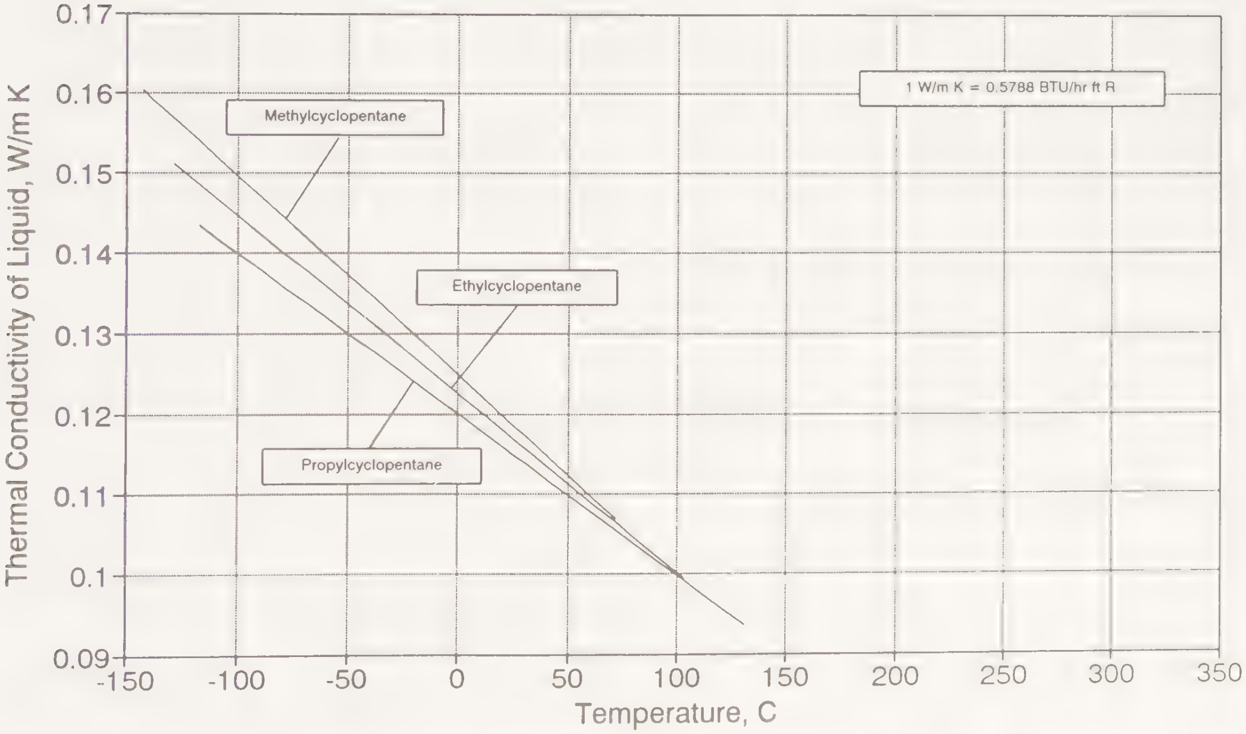

Figure 17-10 Thermal Conductivity of Liquid

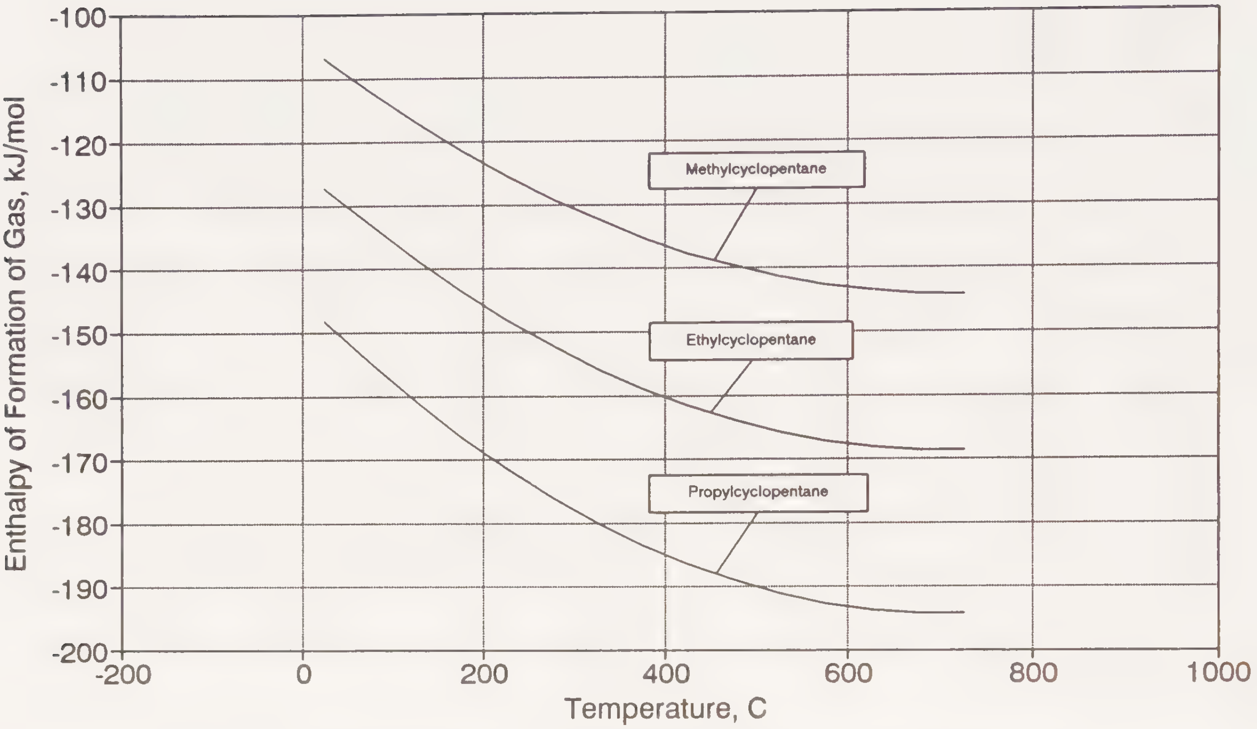

Figure 17-11 Enthalpy of Formation of Gas

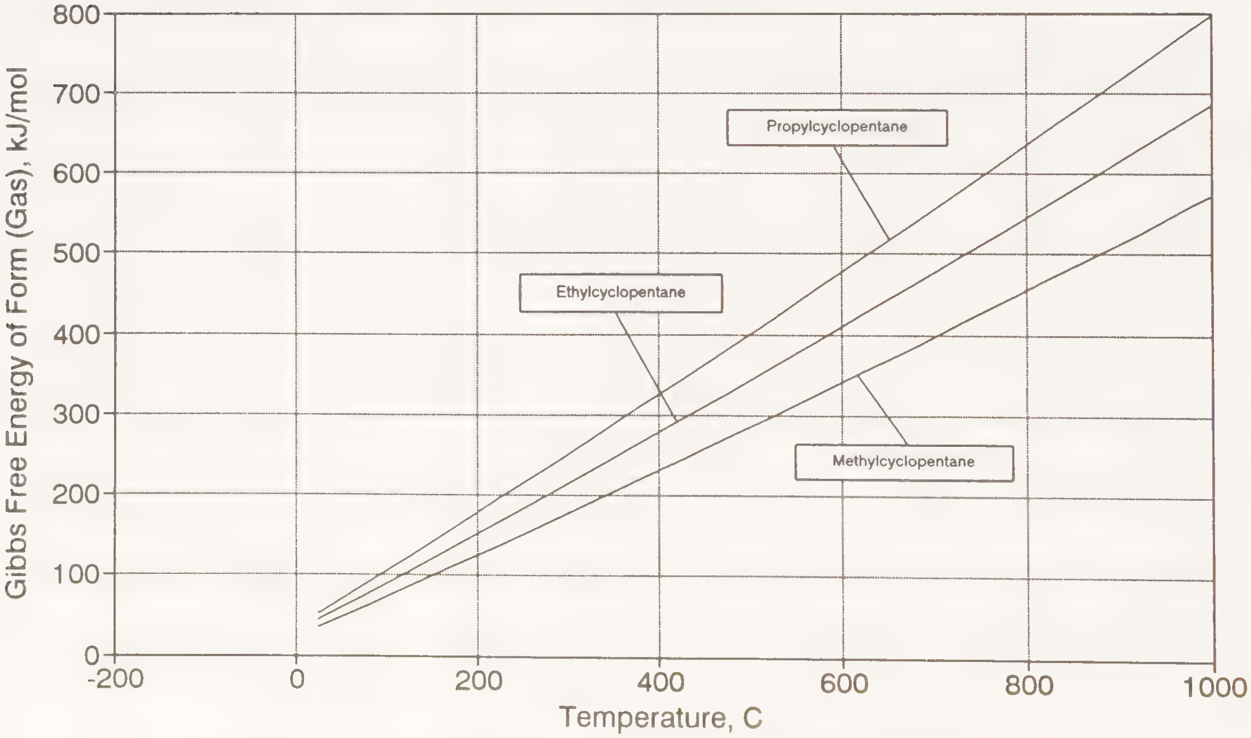

Figure 17-12 Gibbs Free Energy of Formation of Gas

Chapter 18

C_1 TO C_3 NORMAL ALKYL CYCLOHEXANES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 18-1

Property data from the literature (1-23,25-36,38-59,75,83,85,89-99) are given in Table 18-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation, lower explosion limit in air and solubility in water are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 18-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 18-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 3% or less.

LIQUID DENSITY - Figure 18-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density from low temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 18-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 18-5 and 18-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

Results from the DIPPR project (5) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6). Results are in favorable agreement with data. Errors are about 3% or less using the correlation.

VISCOSITY - Figures 18-7 and 18-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 3% or less.

THERMAL CONDUCTIVITY - Figures 18-9 and 18-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 18-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 18-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 18-1 Physical Properties

1. Name	Methylcyclohexane	Ethylcyclohexane	Propylcyclohexane
2. Formula	C7H14	C8H16	C9H18
3. Molecular Weight, g/mol	98.188	112.214	126.241
4. Critical Temperature, K	572.19	609.15	639.15
5. Critical Pressure, bar	34.714	30.398	28.067
6. Critical Volume, ml/mol	368	450	477
7. Critical Compressibility Factor	0.269	0.270	0.252
8. Acentric Factor	0.2350	0.2455	0.2595
9. Melting Point, K	146.58	161.84	178.28
10. Boiling Point @ 1 atm, K	374.08	404.95	429.90
11. Heat of Vaporization @ BP, kJ/kg	317.05	305.72	285.69
12. Density of Liquid @ 25 C, g/ml	0.766	0.784	0.789
13. Surface Tension @ 25 C, dynes/cm	23.334	25.179	26.08
14. Heat Capacity of Gas @ 25 C, J/g K	1.373	1.414	1.458
15. Heat Capacity of Liquid @ 25 C, J/g K	1.882	1.895	1.915
16. Viscosity of Gas @ 25 C, micropoise	65.28	59.00	56.80
17. Viscosity of Liquid @ 25 C, centipoise	0.684	0.786	0.989
18. Thermal Conductivity of Gas @ 25 C, W/m K	0.0137	0.0127	0.0129
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1108	0.1166	0.1144
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-127.26	-172.08	-193.66
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	44.00	38.60	46.62
22. Flash Point, K	269.26	308.15	------
23. Autoignition Temperature, K	558.15	535.37	------
24. Lower Explosion Limit in Air, vol %	1.2	------	0.9
25. Upper Explosion Limit in Air, vol %	------	9.0	------
26. Solubility in Water @ 25 C, ppm(wt)	16.0	2.92	0.68

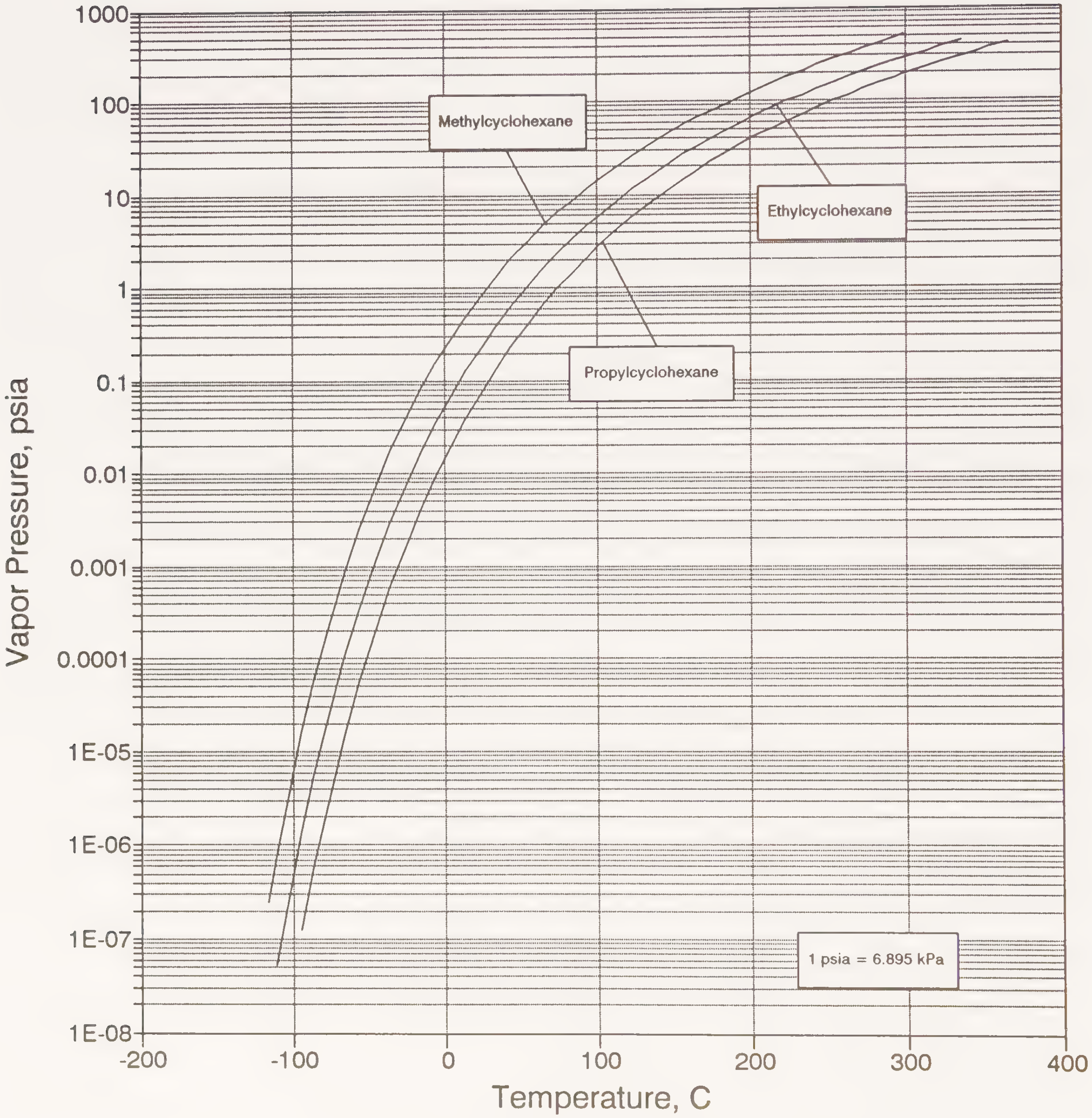

Figure 18-1 Vapor Pressure

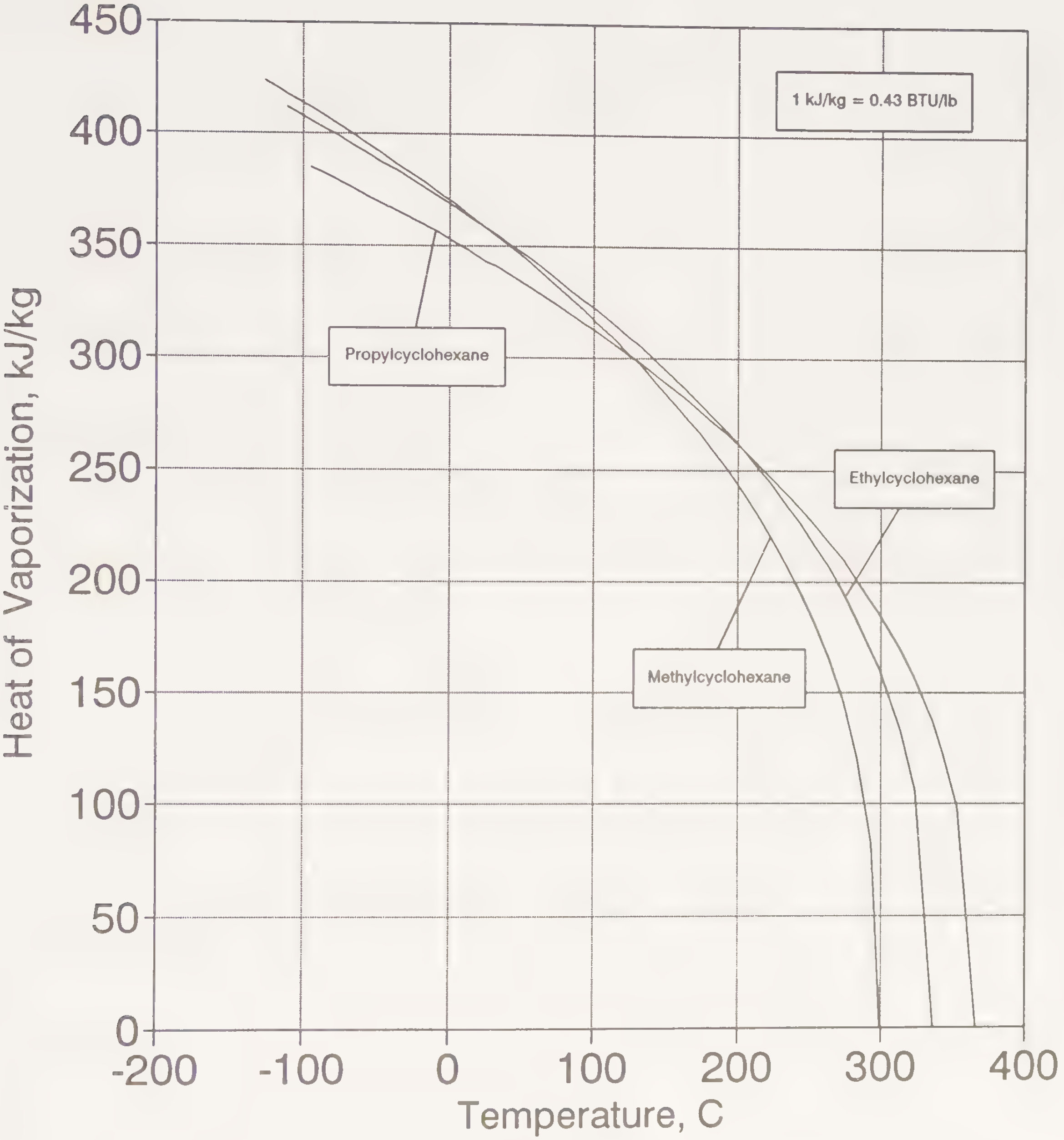

Figure 18-2 Heat of Vaporization

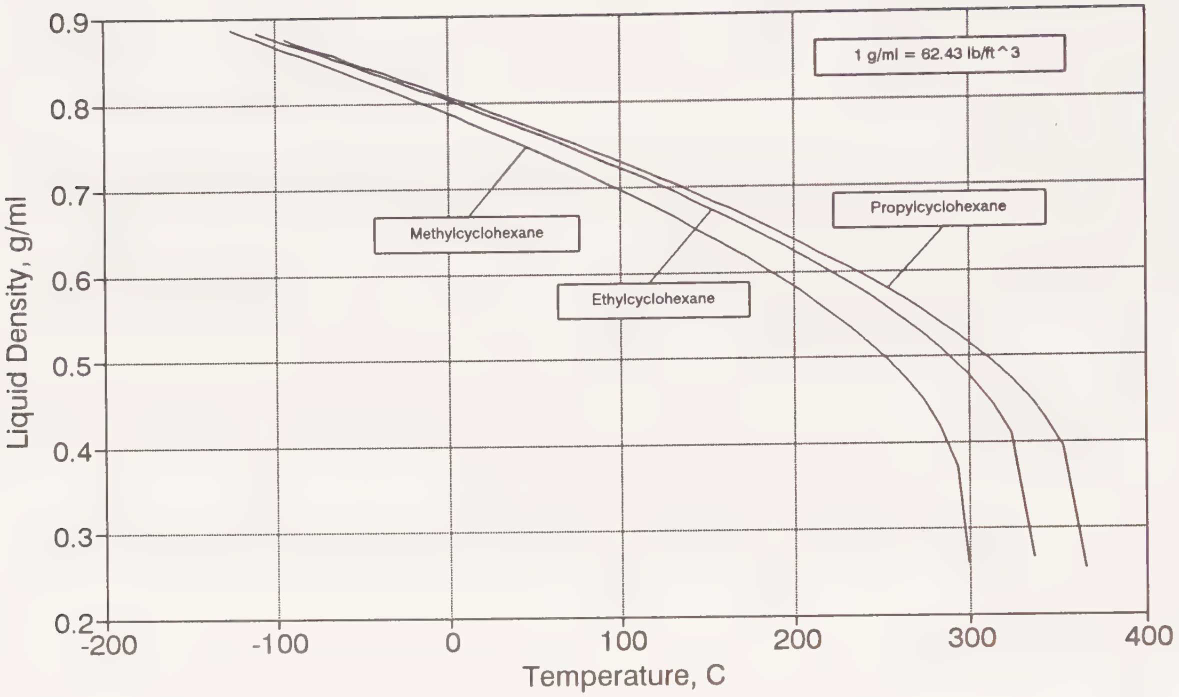

Figure 18-3 Liquid Density

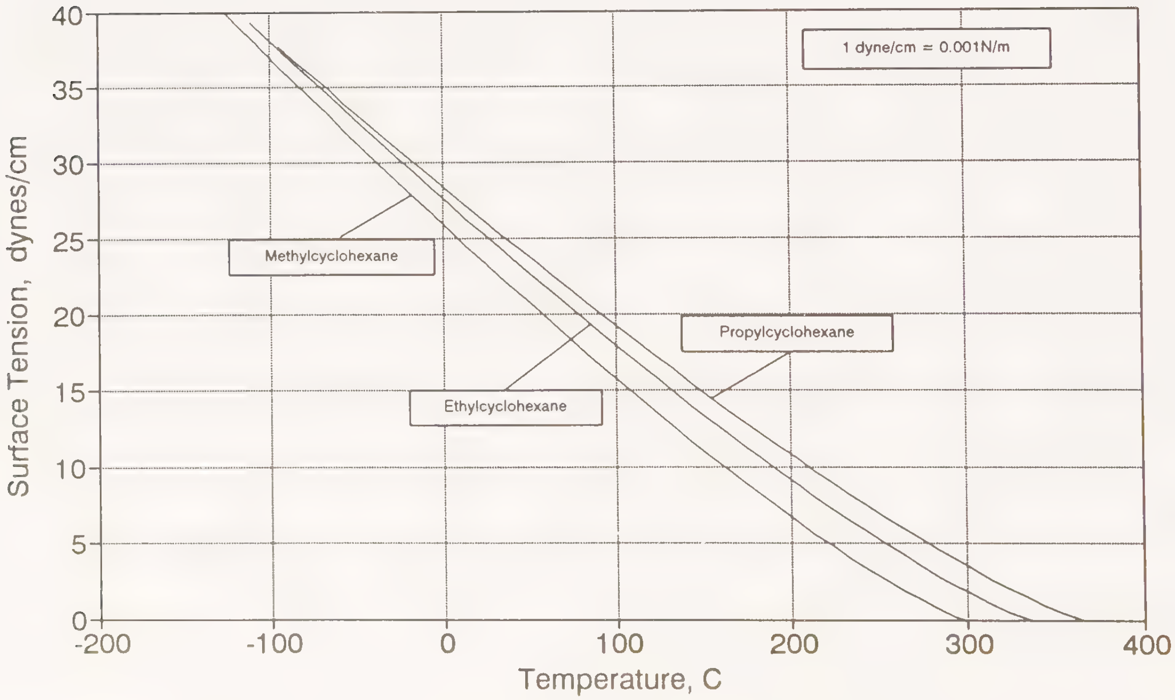

Figure 18-4 Surface Tension

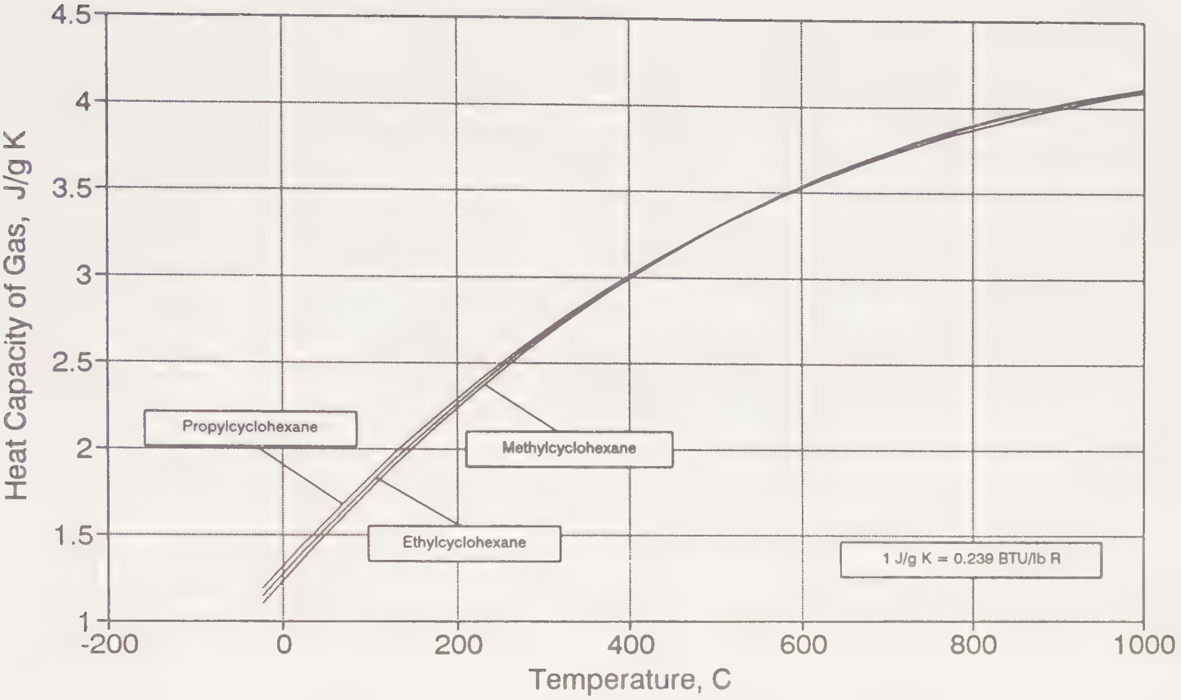

Figure 18-5 Heat Capacity of Gas

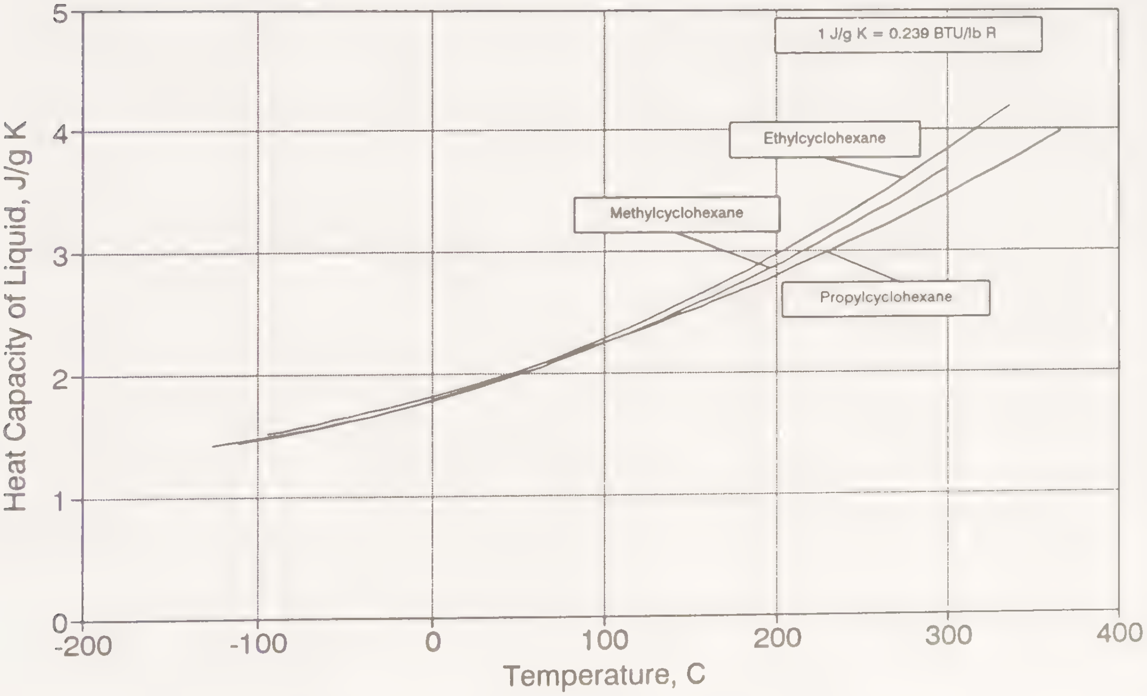

Figure 18-6 Heat Capacity of Liquid

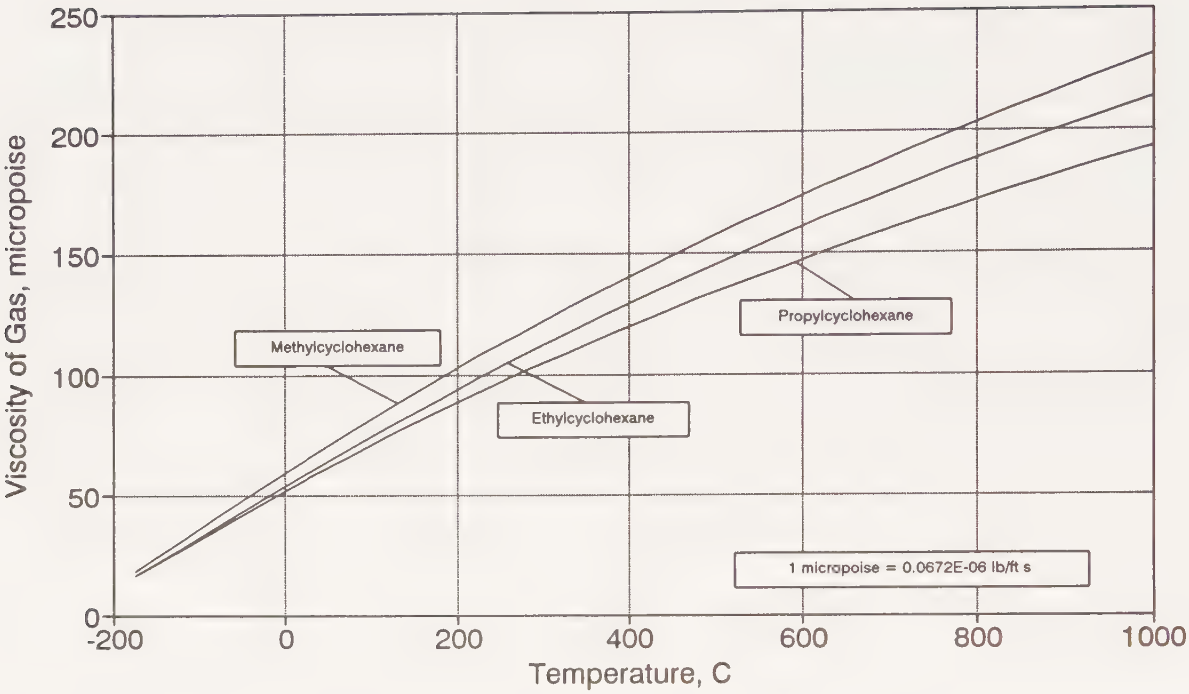

Figure 18-7 Viscosity of Gas

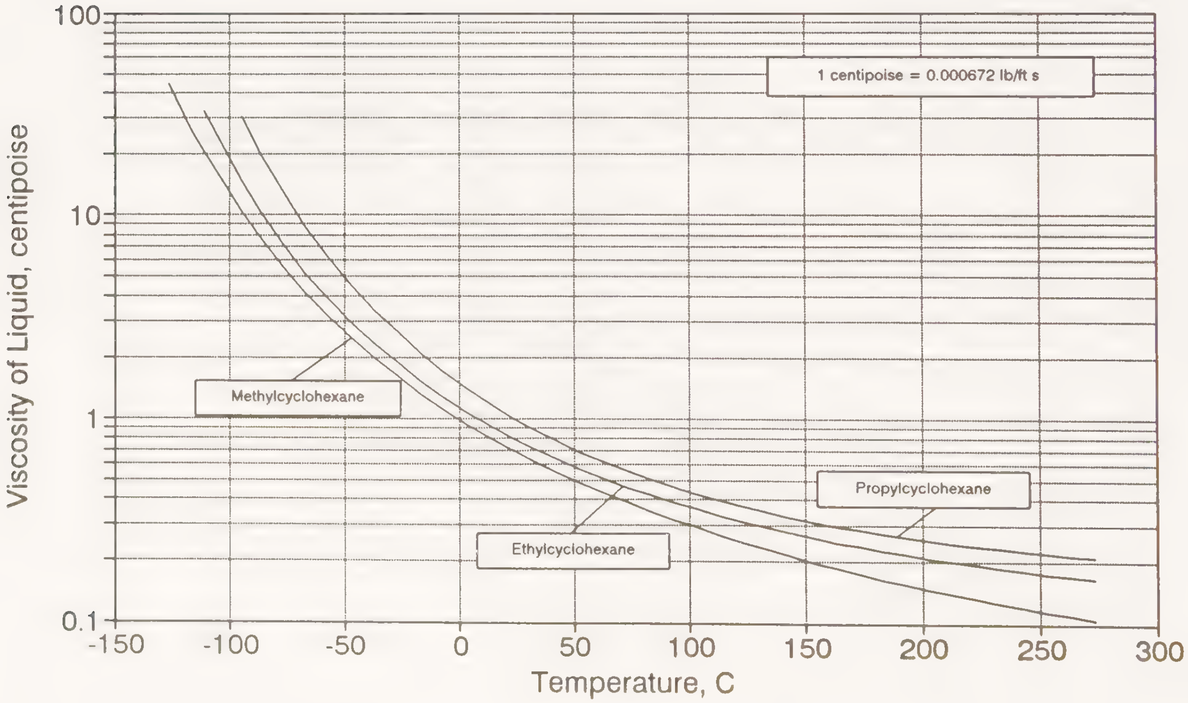

Figure 18-8 Viscosity of Liquid

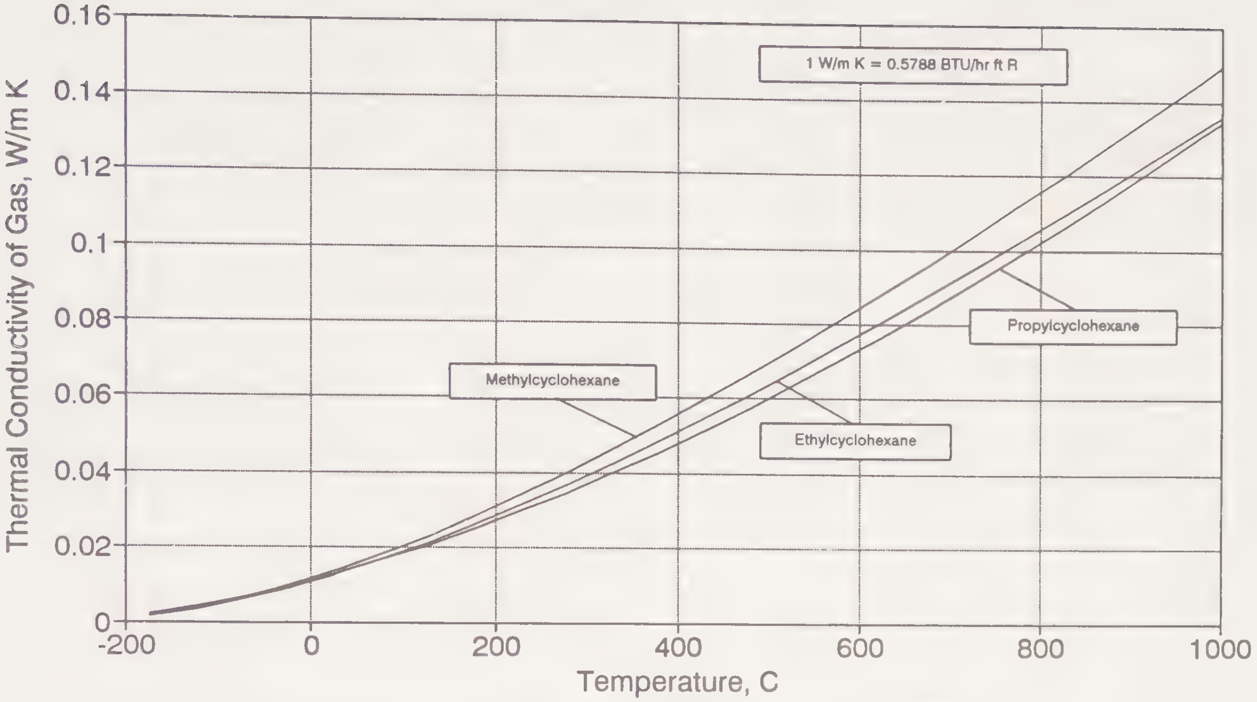

Figure 18-9 Thermal Conductivity of Gas

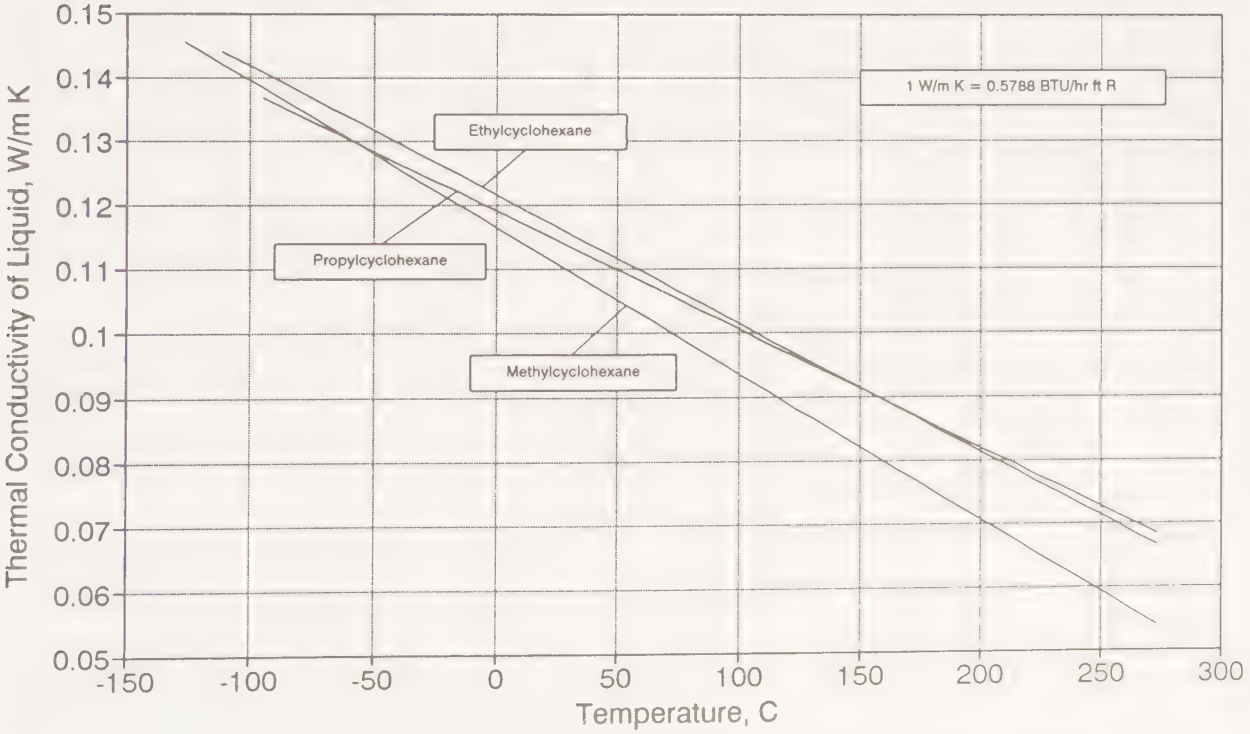

Figure 18-10 Thermal Conductivity of Liquid

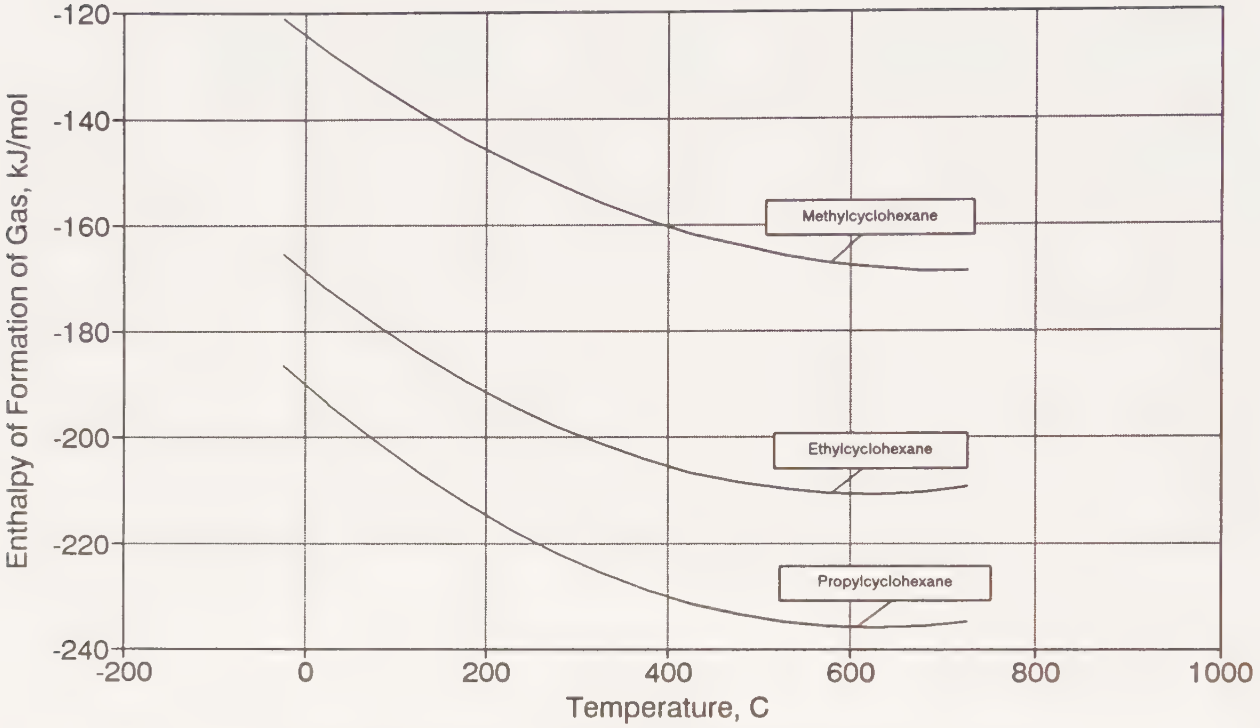

Figure 18-11 Enthalpy of Formation of Gas

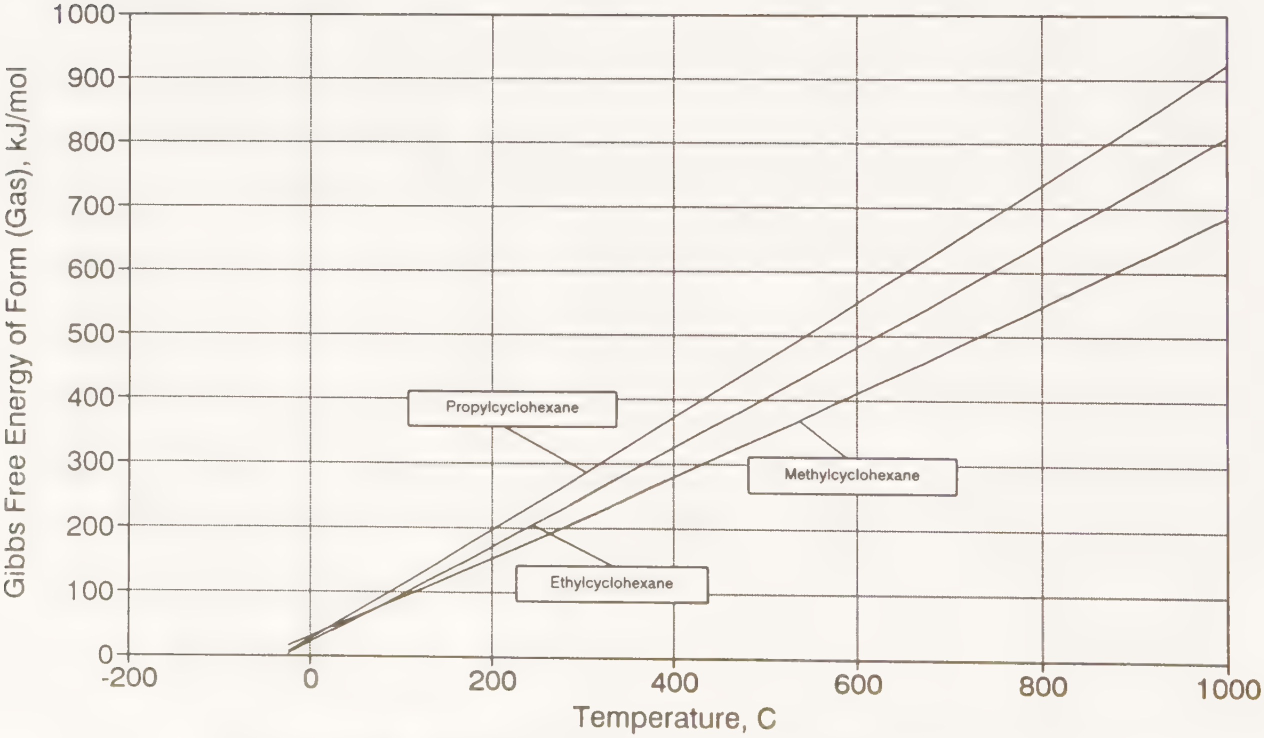

Figure 18-12 Gibbs Free Energy of Formation of Gas

Chapter 19

C_4 TO C_6 NORMAL ALKYL BENZENES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 19-1

Property data from the literature (1-23,25-36,38-59,75,95,97,139,158,166,172,184-187) are given in Table 19-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation and explosion limits in air are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 19-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 19-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 19-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density for all compounds. The range of coverage applies to temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 19-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 5% or less in most cases.

HEAT CAPACITY - Figures 19-5 and 19-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 10% or less except for hexylbenzene (possible 25%).

VISCOSITY - Figures 19-7 and 19-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 19-9 and 19-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 19-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 19-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 19-1 Physical Properties

1. Name	Butylbenzene	Pentylbenzene	Hexylbenzene
2. Formula	C10H14	C11H16	C12H18
3. Molecular Weight, g/mol	134.221	148.248	162.275
4. Critical Temperature, K	660.55	679.90	698.00
5. Critical Pressure, bar	28.868	26.04	23.80
6. Critical Volume, ml/mol	497.00	550.00	618.00
7. Critical Compressibility Factor	0.261	0.253	0.253
8. Acentric Factor	0.3917	0.4388	0.4784
9. Melting Point, K	185.30	198.15	212.00
10. Boiling Point @ 1 atm, K	456.46	478.61	499.26
11. Heat of Vaporization @ BP, kJ/kg	292.37	277.99	265.59
12. Density of Liquid @ 25 C, g/ml	0.856	0.855	0.854
13. Surface Tension @ 25 C, dynes/cm	28.74	28.99	29.55
14. Heat Capacity of Gas @ 25 C, J/g K	1.304	1.335	1.360
15. Heat Capacity of Liquid @ 25 C, J/g K	1.773	1.829	1.859
16. Viscosity of Gas @ 25 C, micropoise	------	54.64	------
17. Viscosity of Liquid @ 25 C, centipoise	0.960	1.259	1.534
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1266	0.1194	0.1171
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-14.00	-34.65	-55.28
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	144.20	152.37	160.73
22. Flash Point, K	344.26	339.00	356.00
23. Autoignition Temperature, K	685.37	------	------
24. Lower Explosion Limit in Air, vol %	0.8	0.7	0.7
25. Upper Explosion Limit in Air, vol %	5.8	5.1	5.0
26. Solubility in Water @ 25 C, ppm(wt)	13.82	3.84	1.018

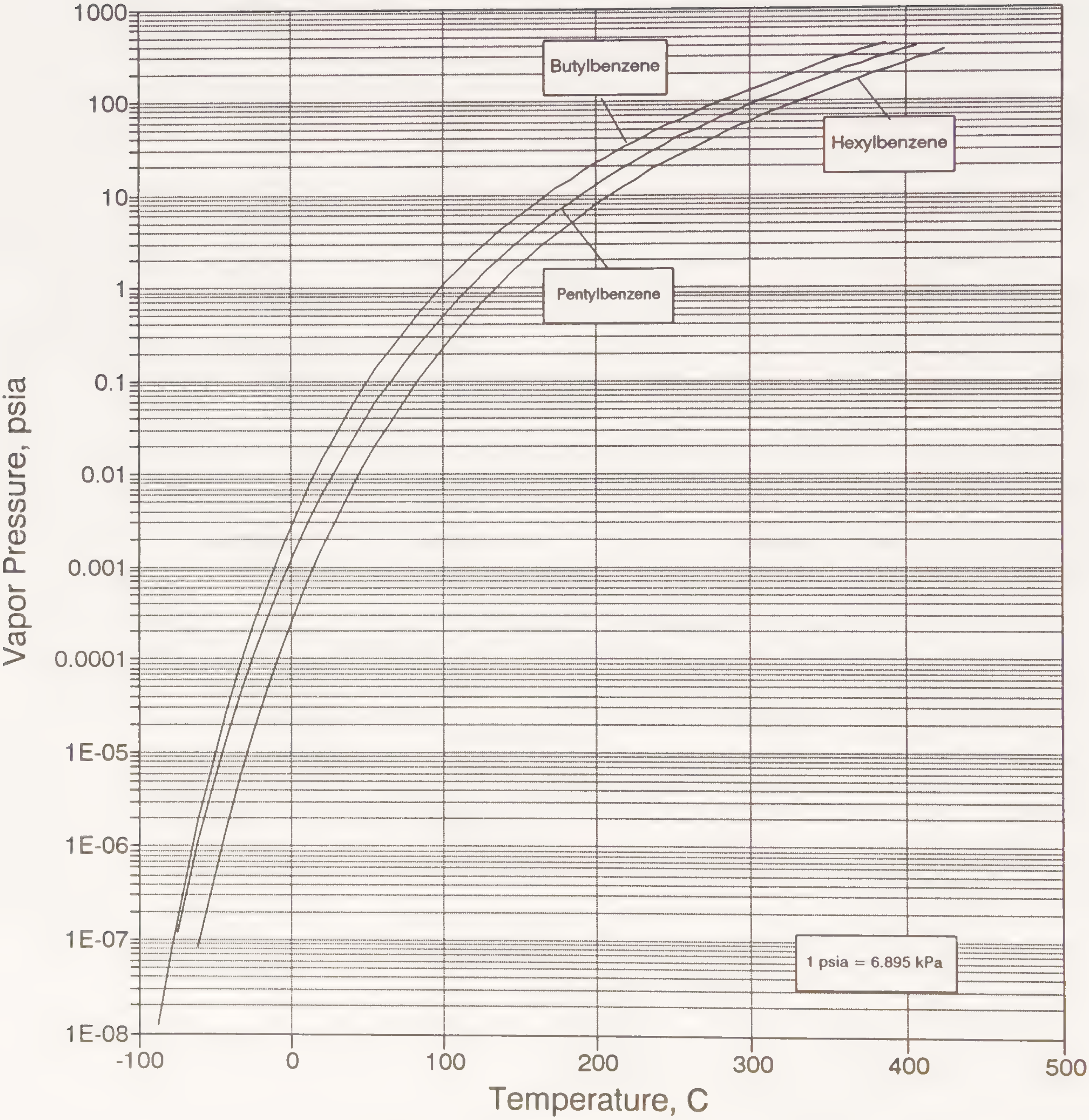

Figure 19-1 Vapor Pressure

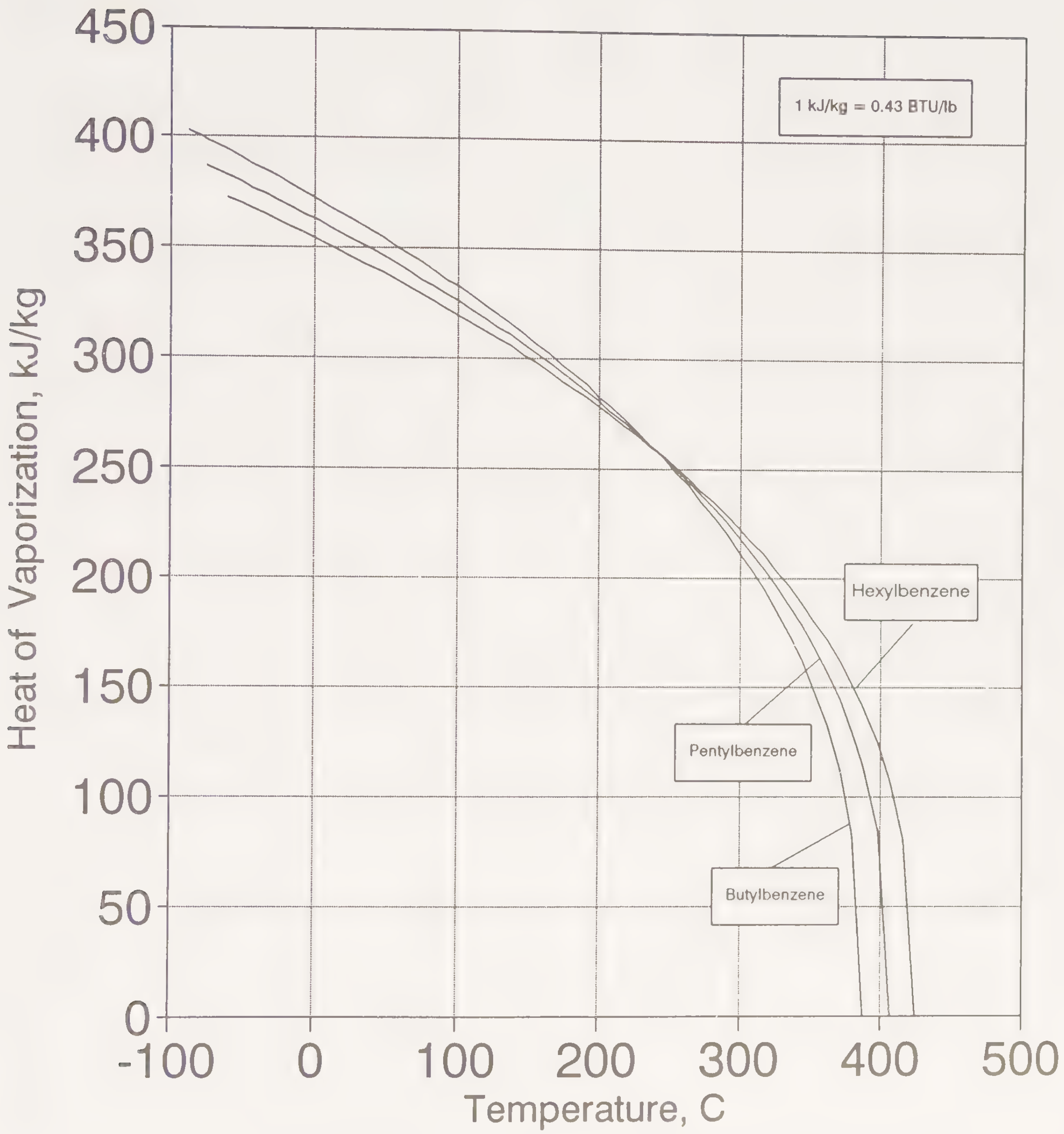

Figure 19-2 Heat of Vaporization

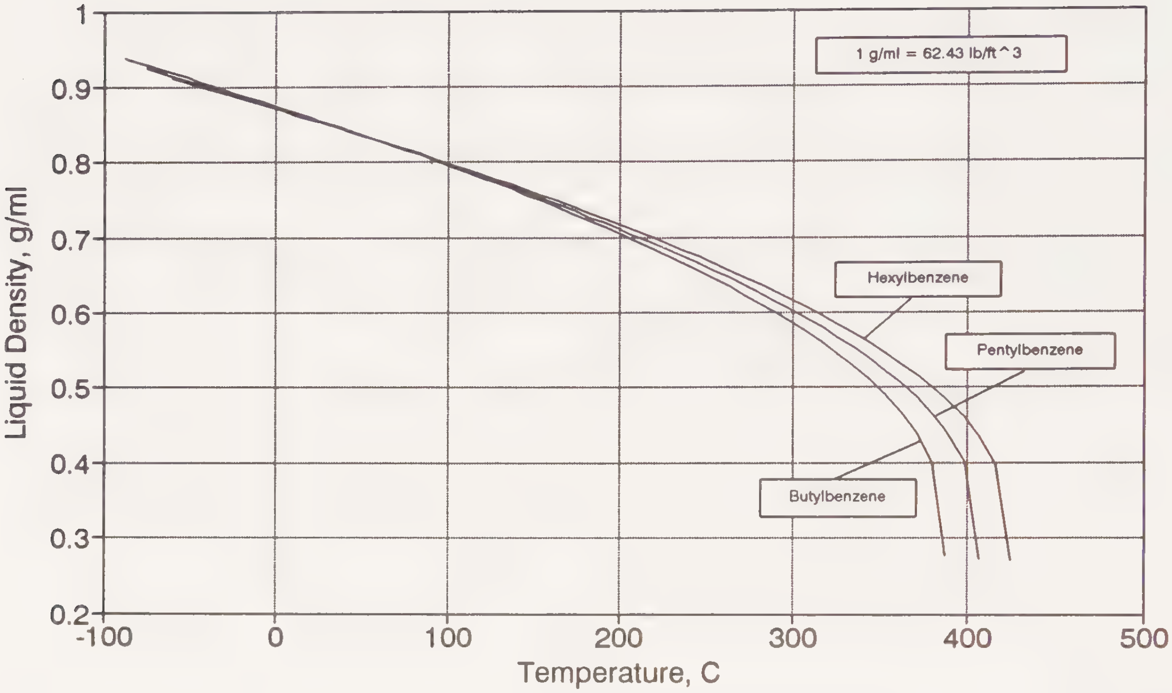

Figure 19-3 Liquid Density

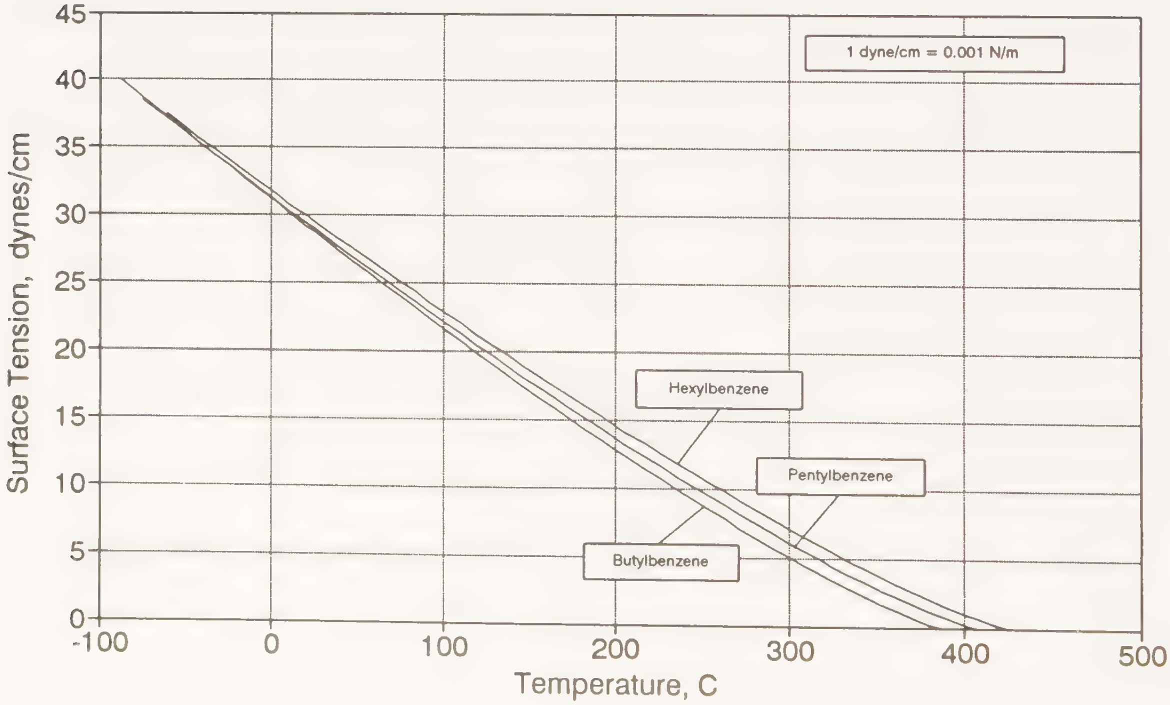

Figure 19-4 Surface Tension

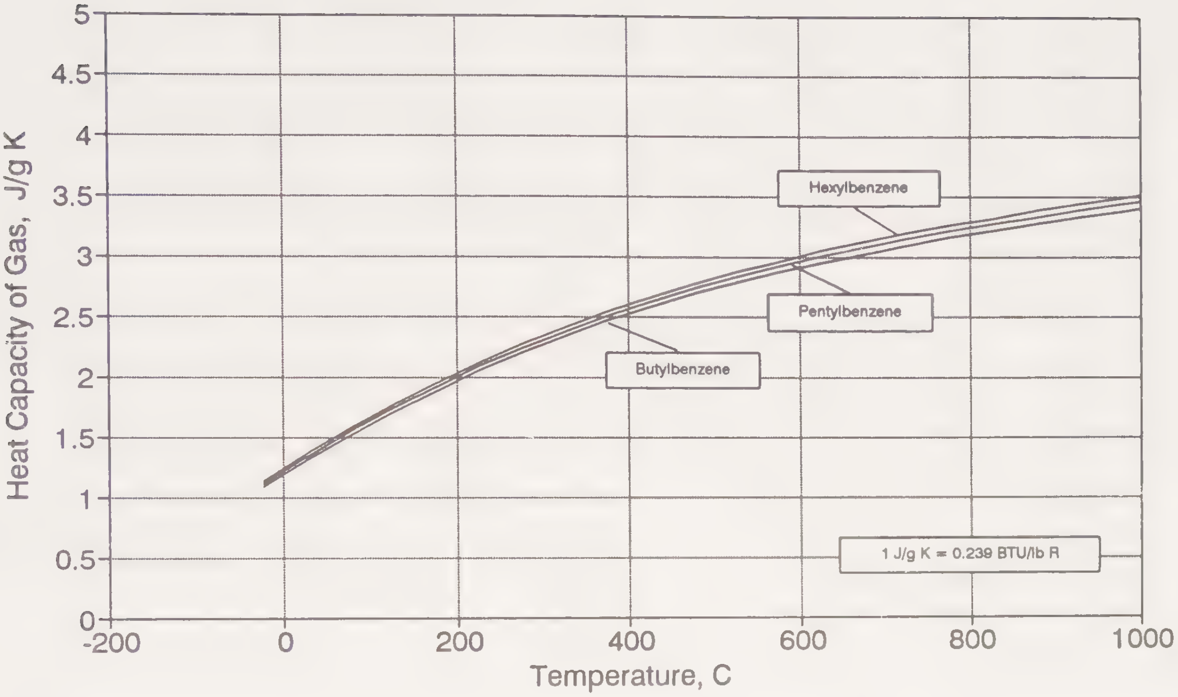

Figure 19-5 Heat Capacity of Gas

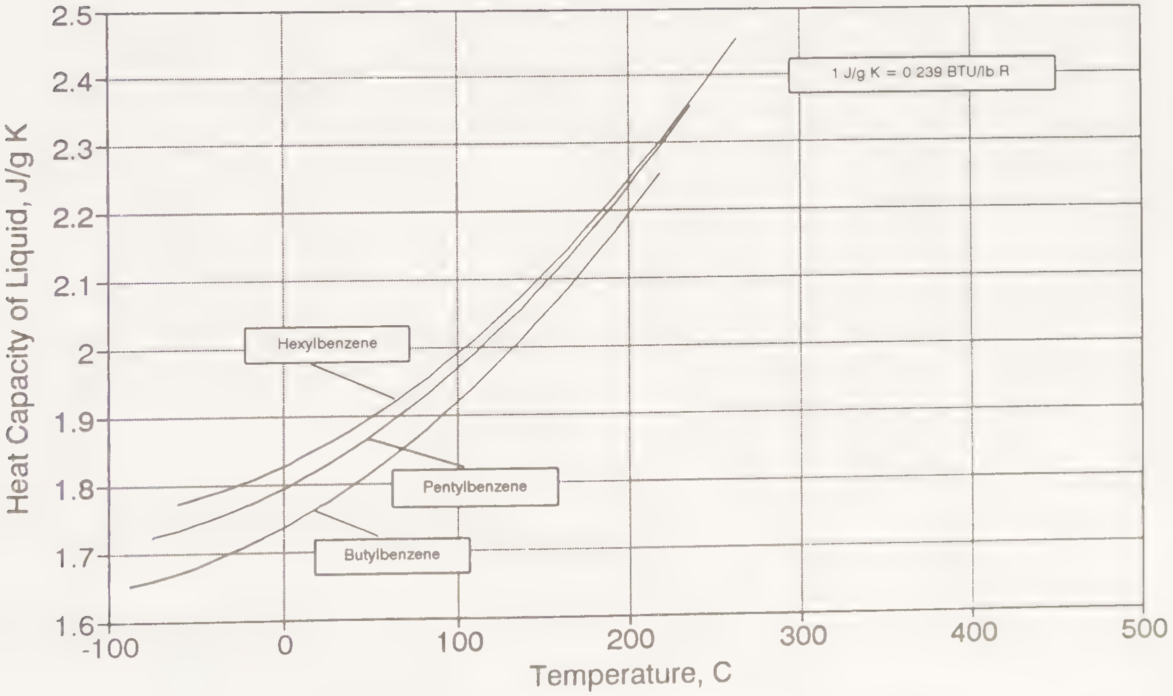

Figure 19-6 Heat Capacity of Liquid

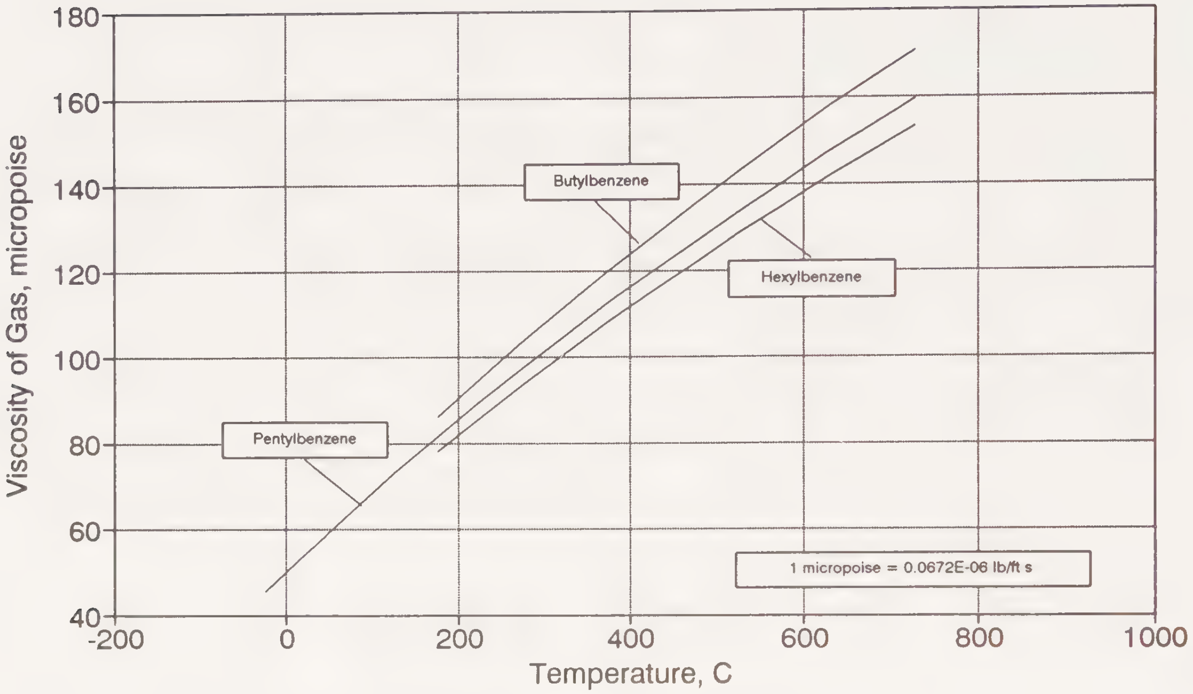

Figure 19-7 Viscosity of Gas

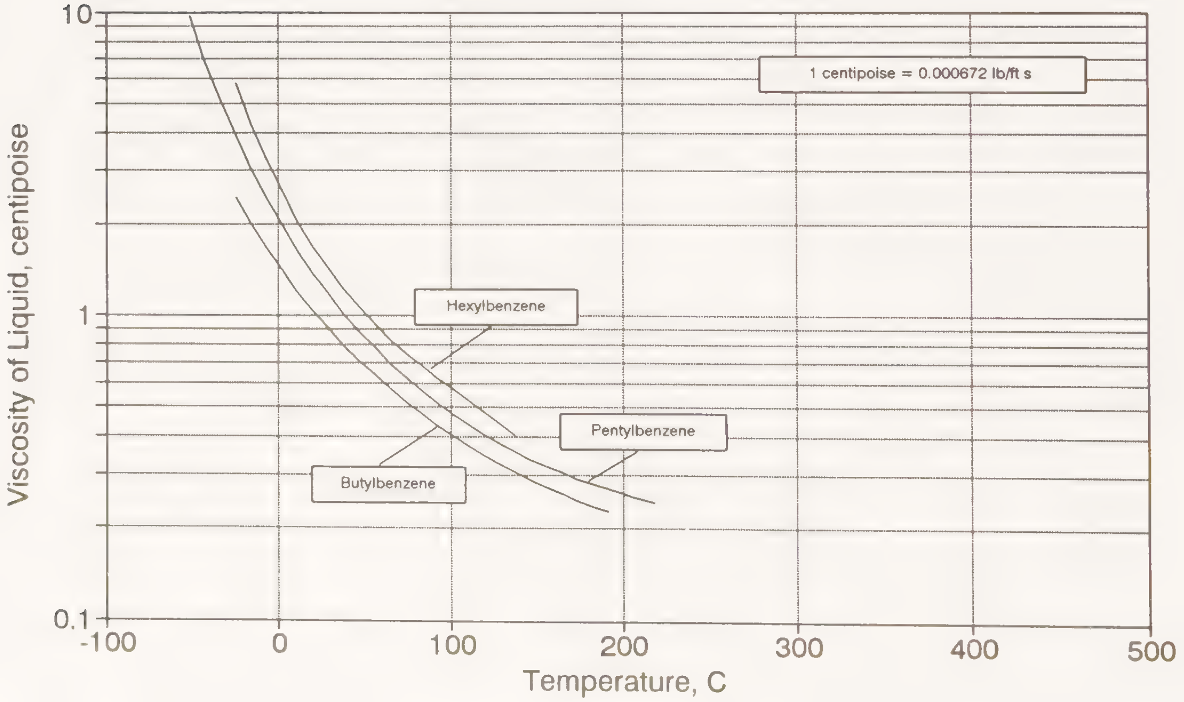

Figure 19-8 Viscosity of Liquid

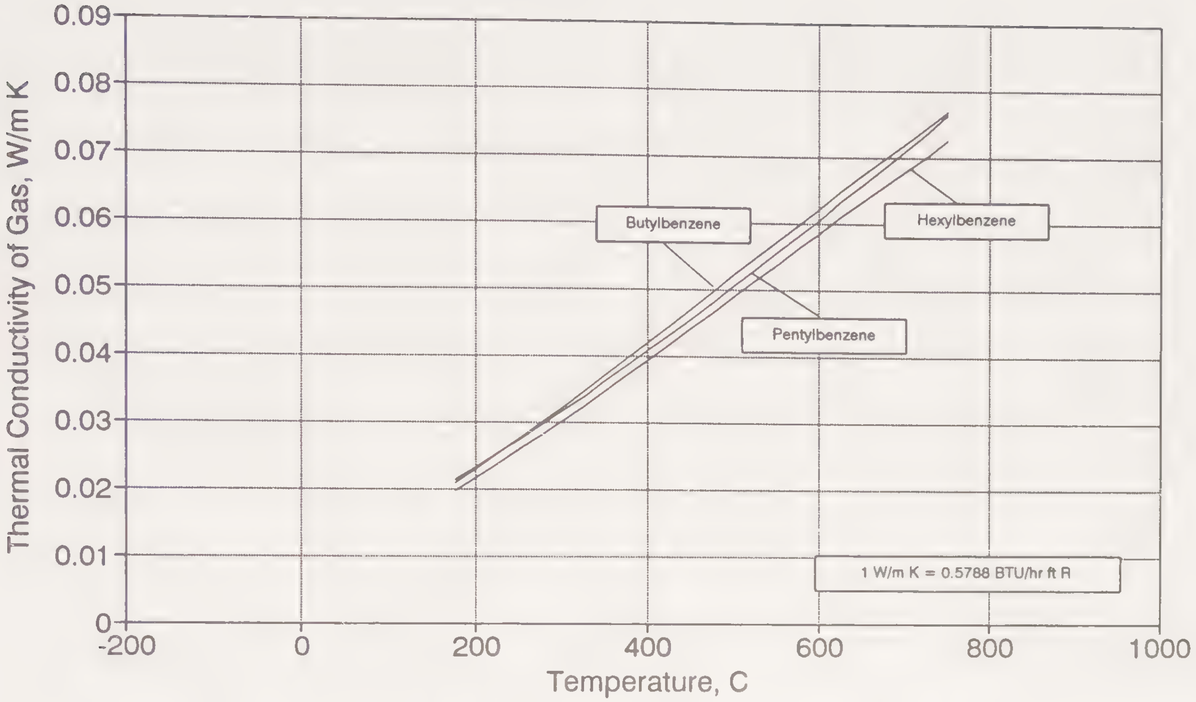

Figure 19-9 Thermal Conductivity of Gas

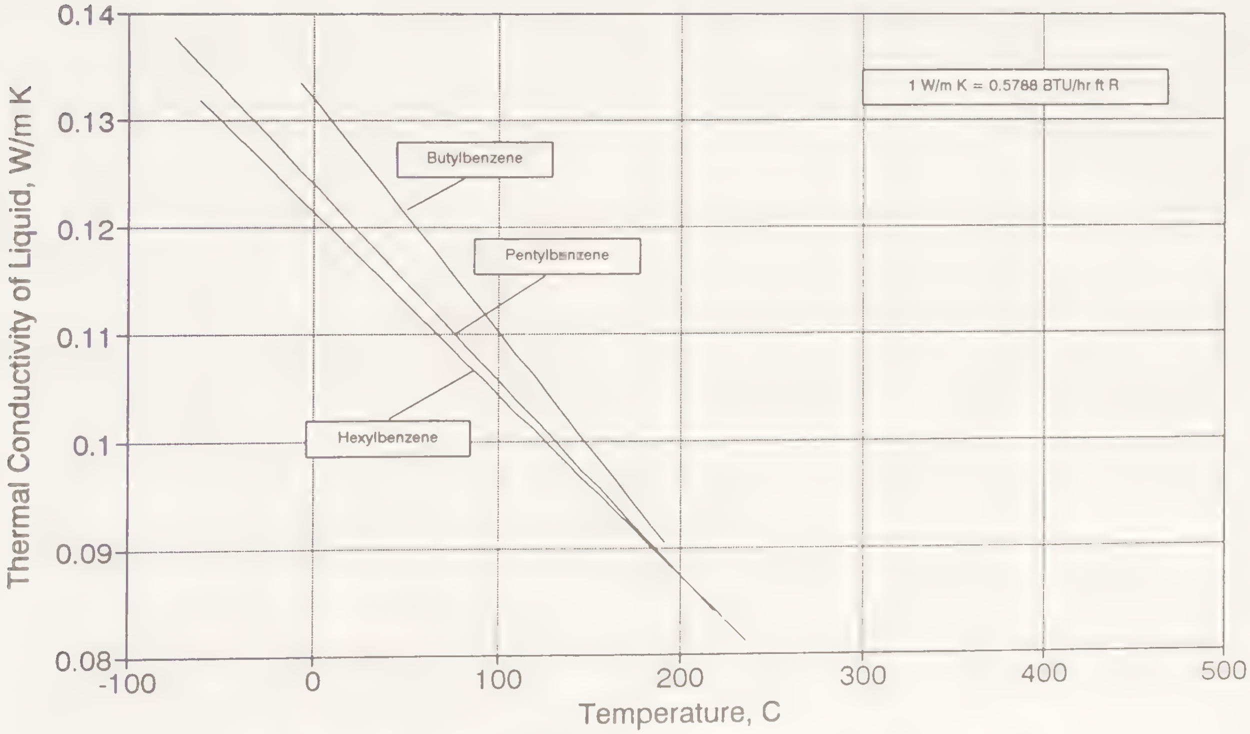

Figure 19-10 Thermal Conductivity of Liquid

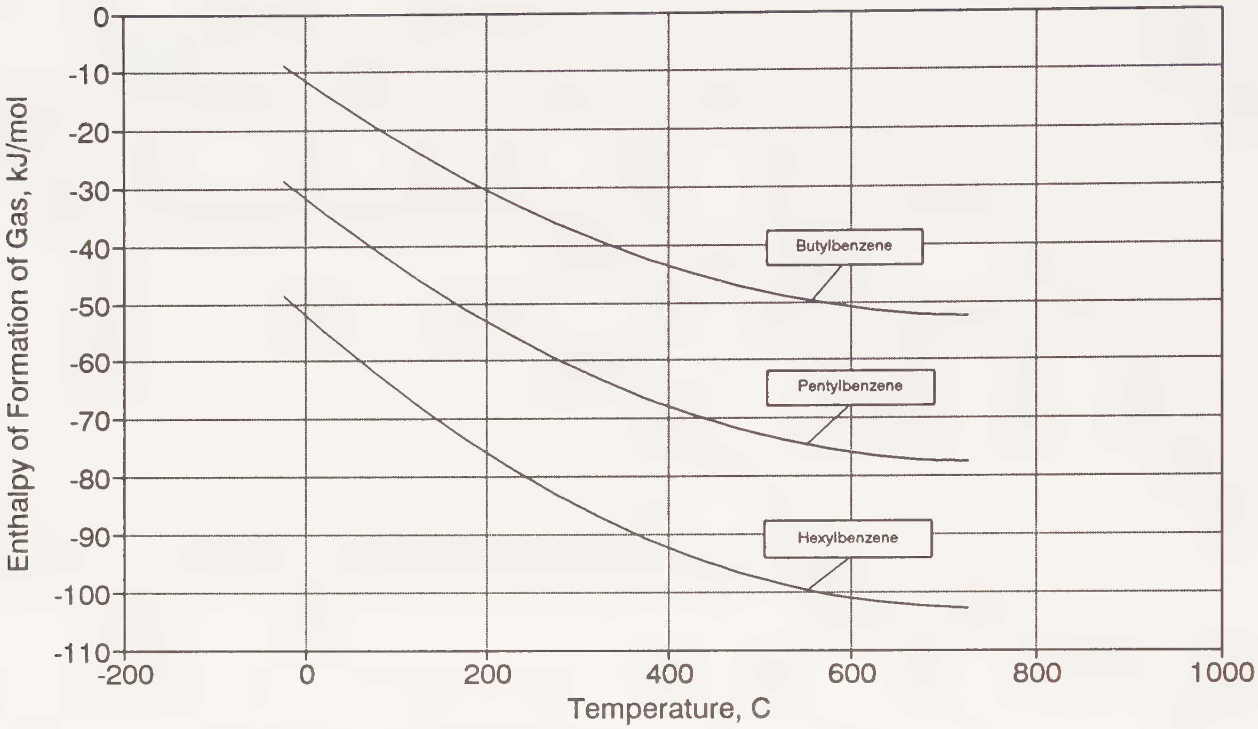

Figure 19-11 Enthalpy of Formation of Gas

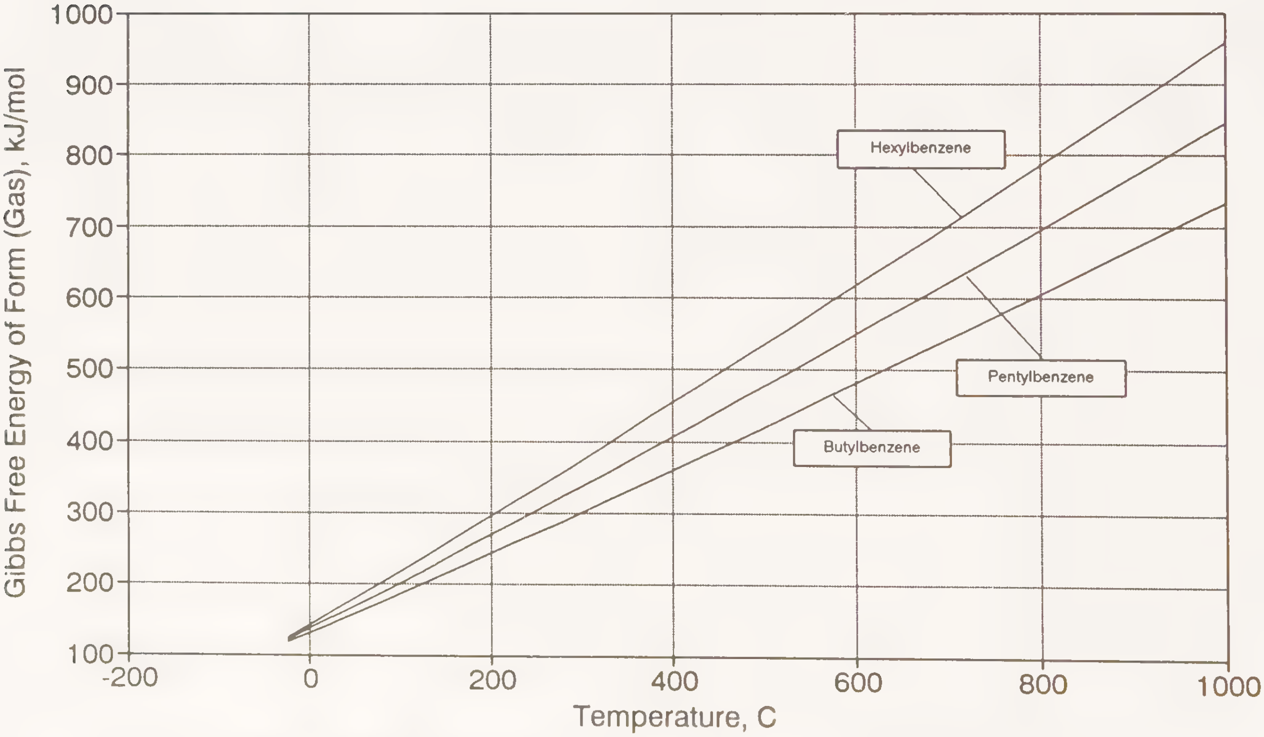

Figure 19-12 Gibbs Free Energy of Formation of Gas

Chapter 20

C_7 TO C_9 NORMAL ALKYL BENZENES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 20-1

Property data from the literature (1-23,25-36,38-59,75,95,97,139,158,189) are given in Table 20-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation and explosion limits in air are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 20-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 5% or less in most cases.

HEAT OF VAPORIZATION - Figure 20-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 20-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density for all compounds. The range of coverage applies to temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 5% in most cases.

SURFACE TENSION - Figure 20-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 5% or less in most cases.

HEAT CAPACITY - Figures 20-5 and 20-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). The results should be considered as rough estimates.

VISCOSITY - Figures 20-7 and 20-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 20-9 and 20-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 20-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 20-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 20-1 Physical Properties

1. Name	Heptylbenzene	Octylbenzene	Nonylbenzene
2. Formula	$C_{13}H_{20}$	$C_{14}H_{22}$	$C_{15}H_{24}$
3. Molecular Weight, g/mol	176.302	190.329	204.356
4. Critical Temperature, K	714.00	729.00	741.00
5. Critical Pressure, bar	21.80	20.20	18.95
6. Critical Volume, ml/mol	648.00	703.00	790.00
7. Critical Compressibility Factor	0.238	0.234	0.243
8. Acentric Factor	0.5287	0.5720	0.6380
9. Melting Point, K	225.15	237.15	249.00
10. Boiling Point @ 1 atm, K	519.25	537.55	555.20
11. Heat of Vaporization @ BP, kJ/kg	256.28	246.23	239.55
12. Density of Liquid @ 25 C, g/ml	0.853	0.853	0.852
13. Surface Tension @ 25 C, dynes/cm	29.80	30.10	30.40
14. Heat Capacity of Gas @ 25 C, J/g K	1.381	1.400	1.415
15. Heat Capacity of Liquid @ 25 C, J/g K	1.886	1.904	1.920
16. Viscosity of Gas @ 25 C, micropoise	50.14	48.29	47.03
17. Viscosity of Liquid @ 25 C, centipoise	1.917	2.347	2.897
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1149	0.1131	0.1114
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-75.90	-96.53	-117.19
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	169.06	177.45	185.75
22. Flash Point, K	368.15	380.15	394.00
23. Autoignition Temperature, K	------	------	------
24. Lower Explosion Limit in Air, vol %	0.6	0.6	0.5
25. Upper Explosion Limit in Air, vol %	4.9	4.9	4.9
26. Solubility in Water @ 25 C, ppm(wt)	0.474	0.250	0.161

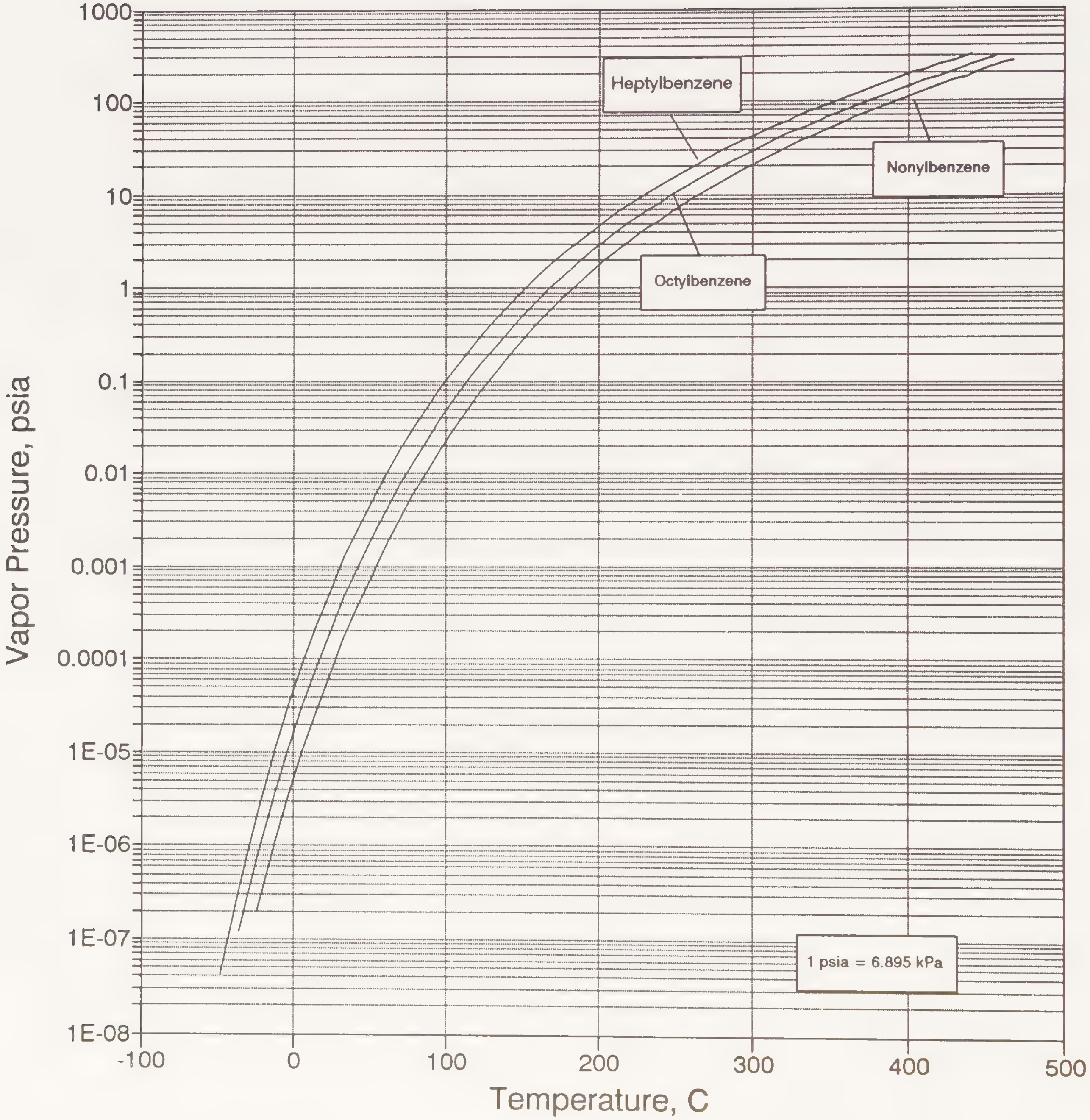

Figure 20-1 Vapor Pressure

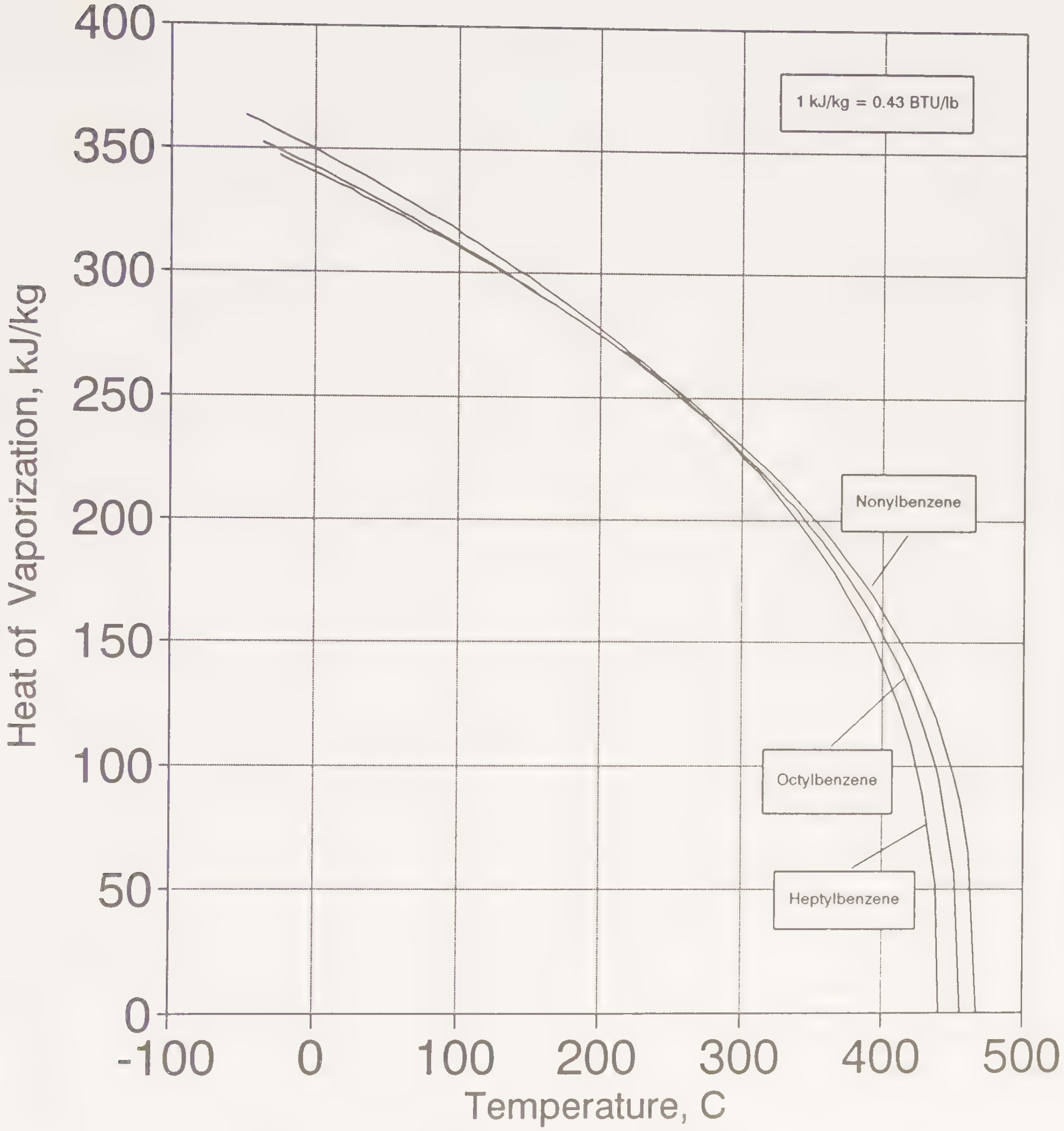

Figure 20-2 Heat of Vaporization

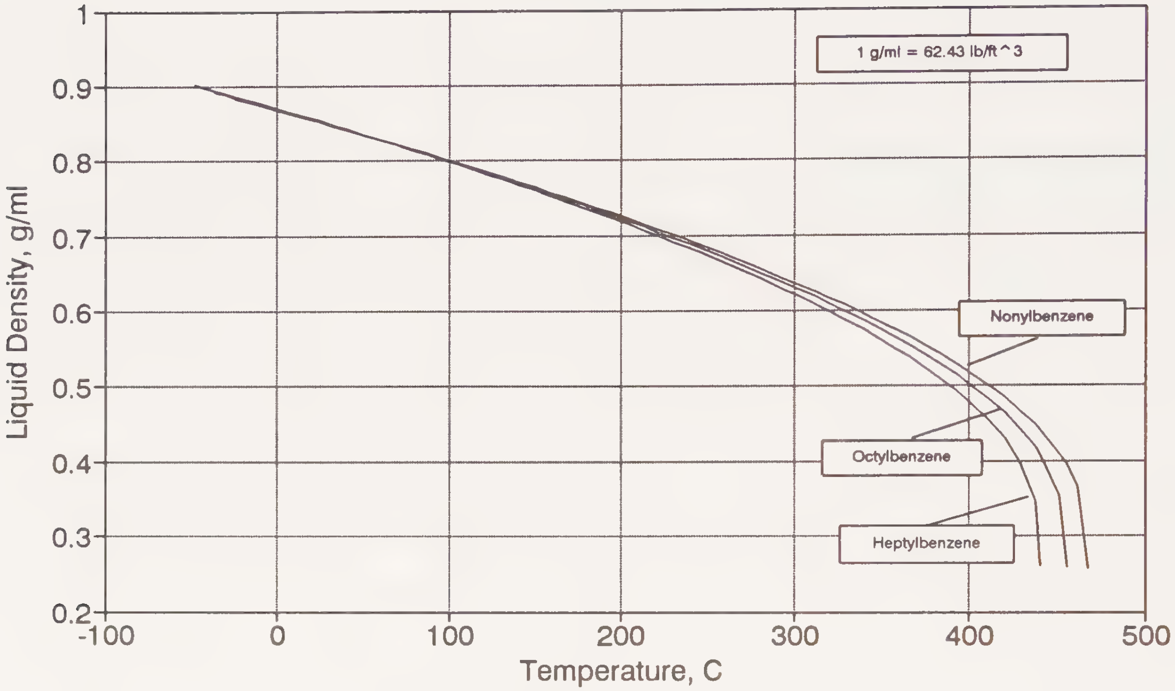

Figure 20-3 Liquid Density

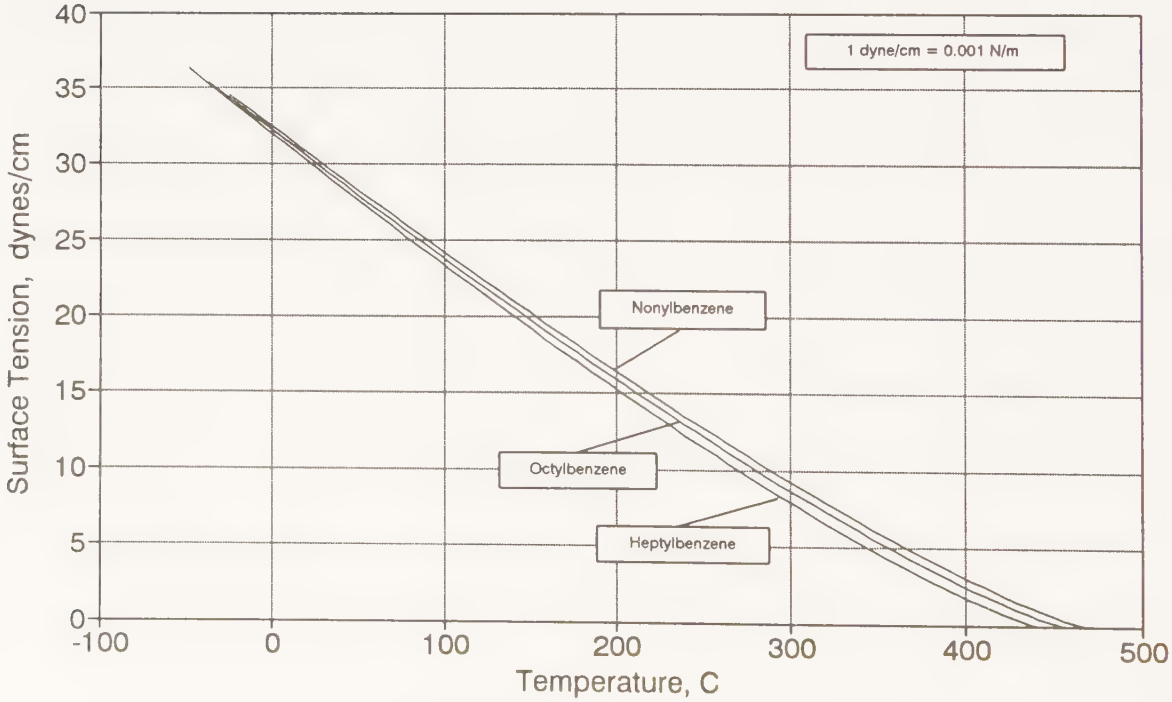

Figure 20-4 Surface Tension

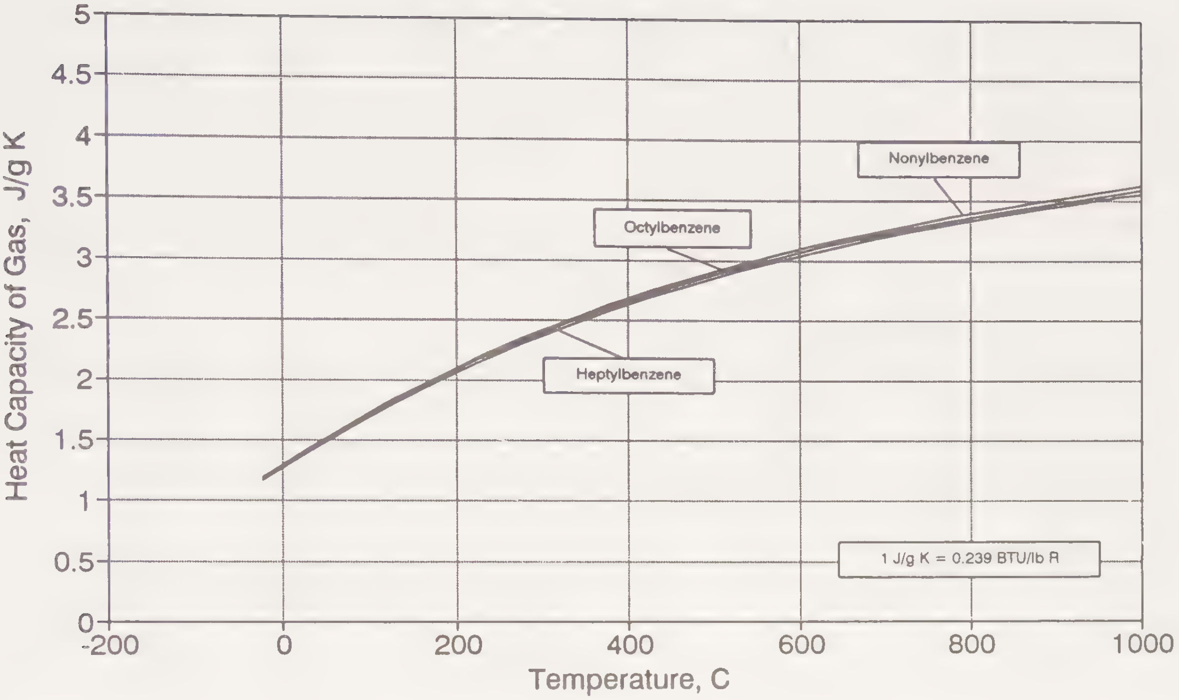

Figure 20-5 Heat Capacity of Gas

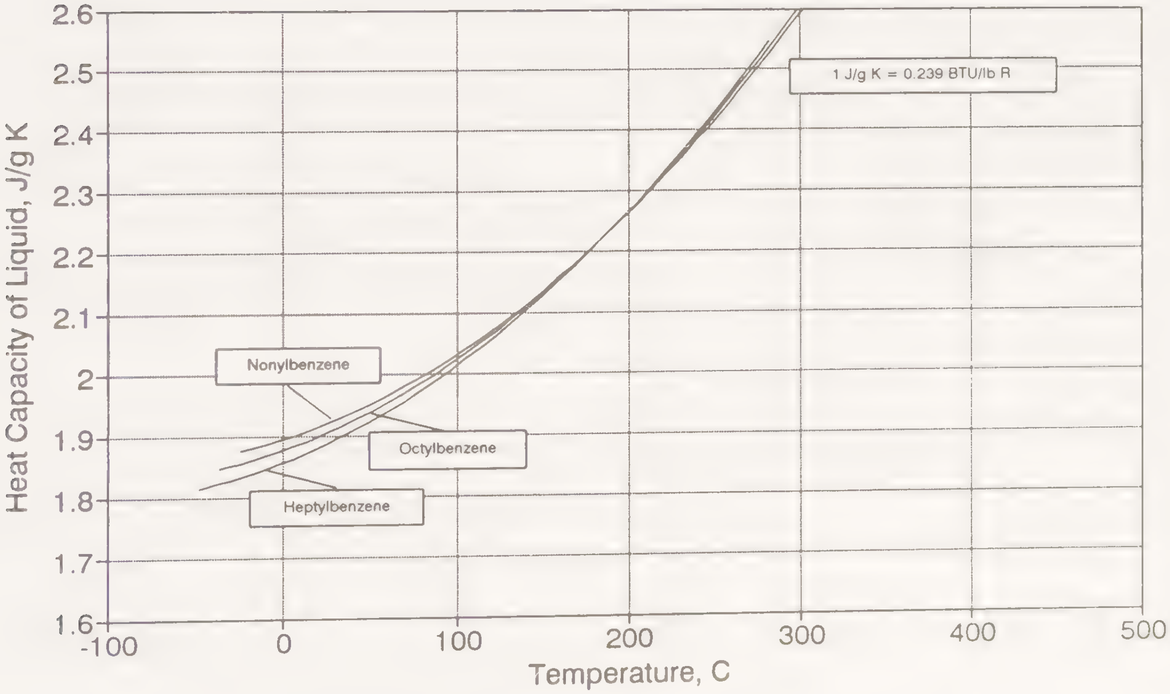

Figure 20-6 Heat Capacity of Liquid

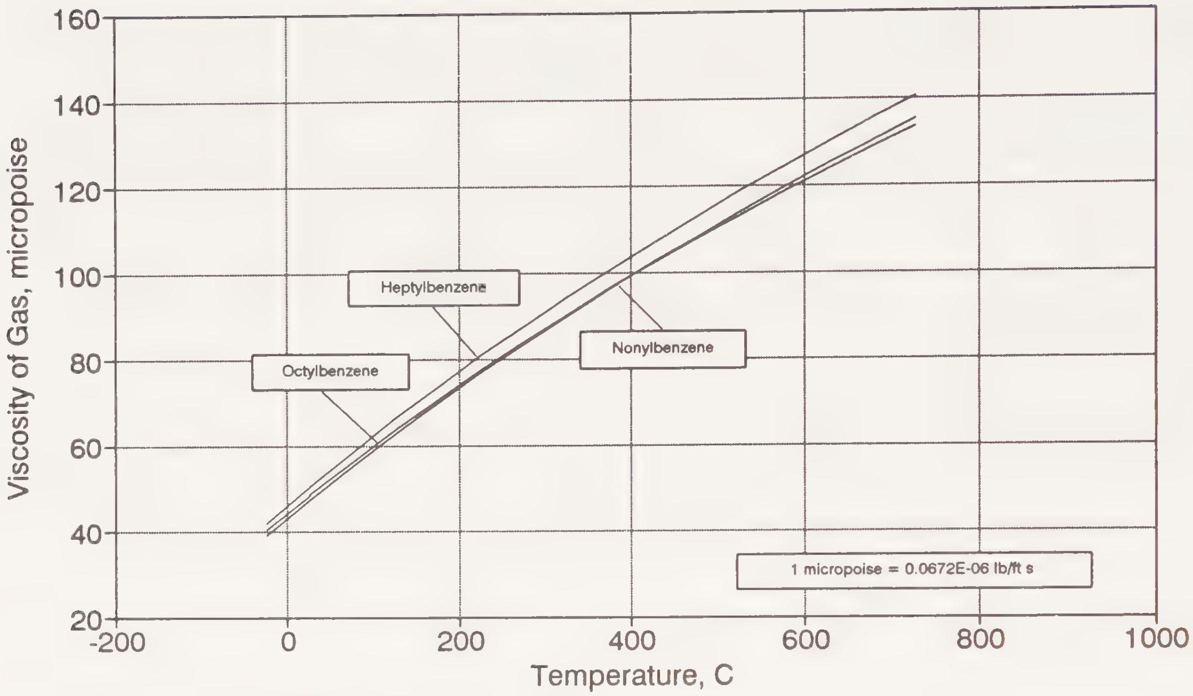

Figure 20-7 Viscosity of Gas

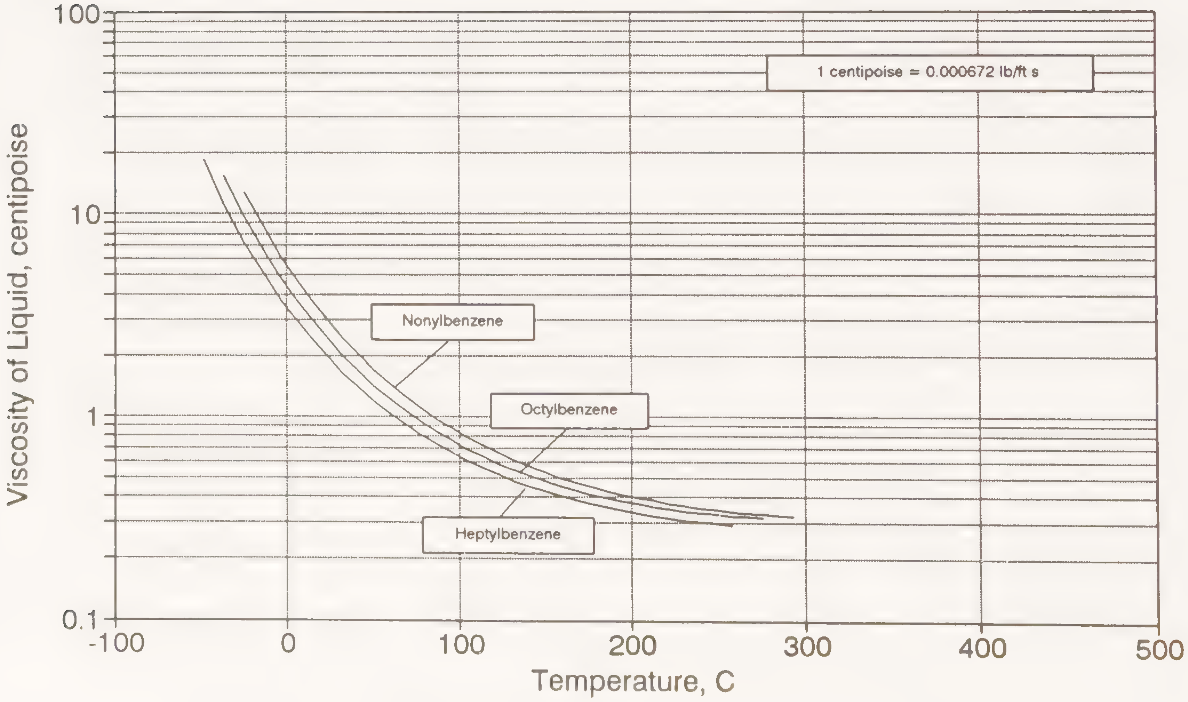

Figure 20-8 Viscosity of Liquid

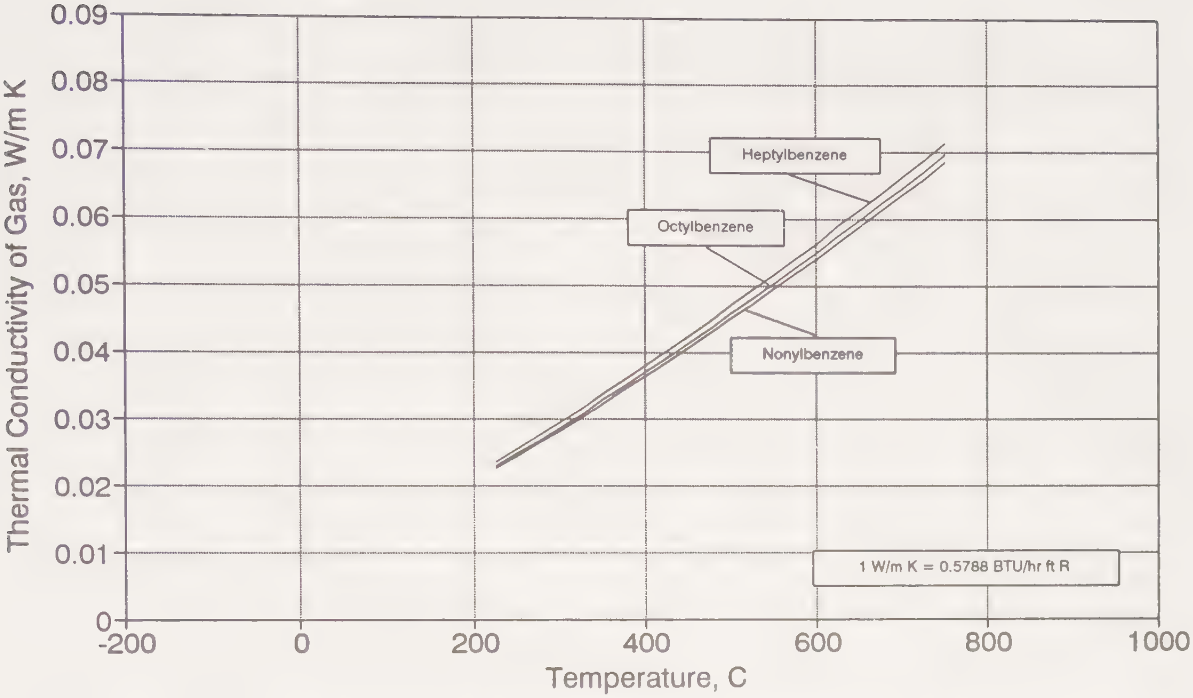

Figure 20-9 Thermal Conductivity of Gas

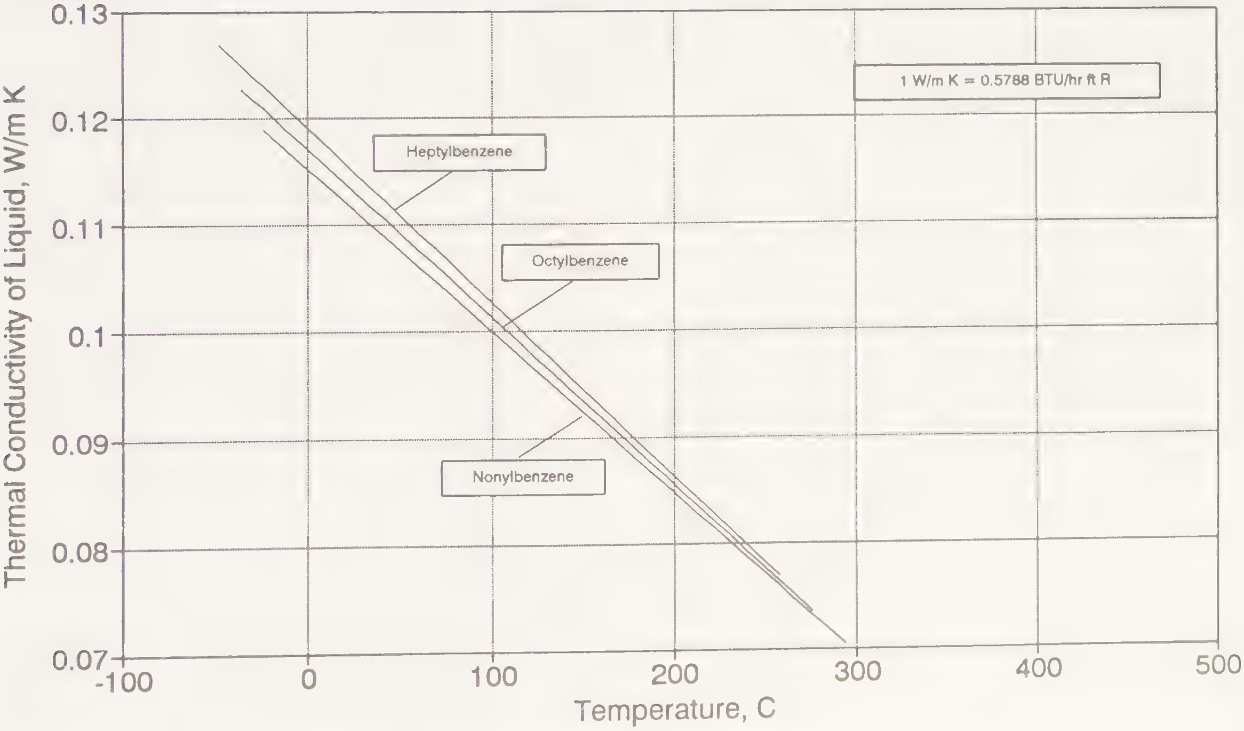

Figure 20-10 Thermal Conductivity of Liquid

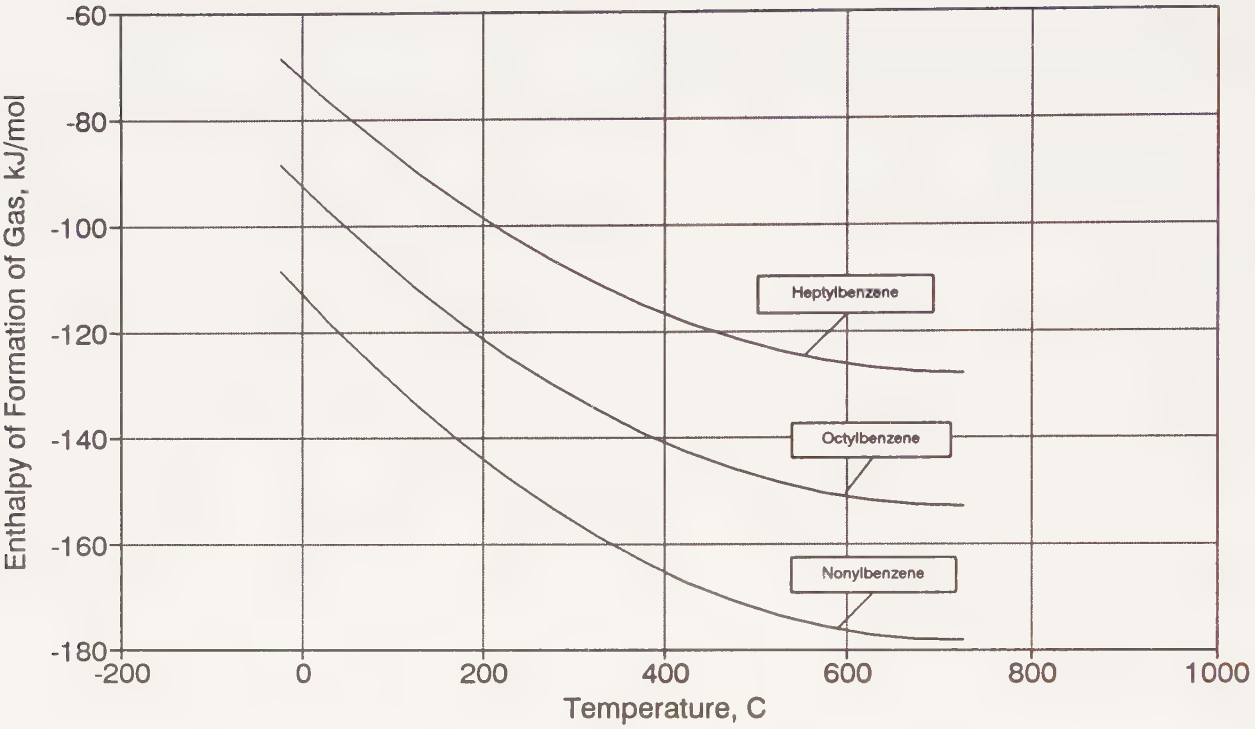

Figure 20-11 Enthalpy of Formation of Gas

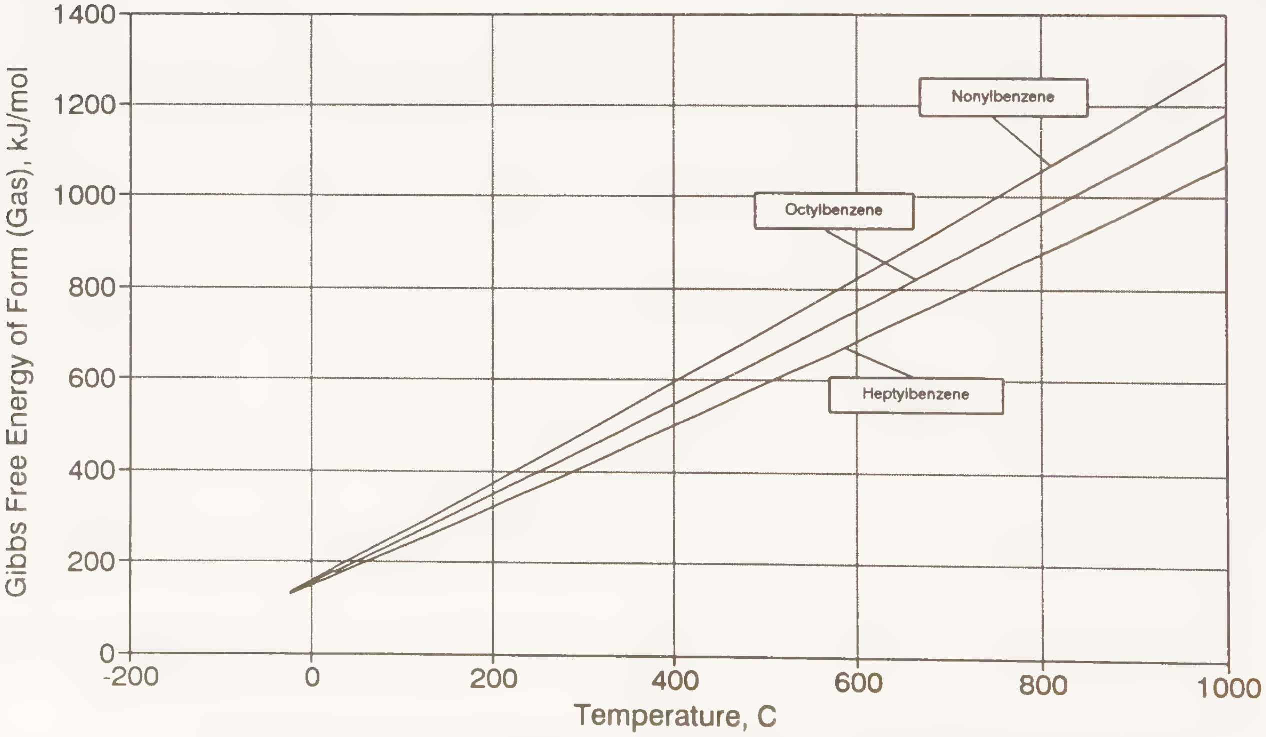

Figure 20-12 Gibbs Free Energy of Formation of Gas

Chapter 21

C_{10} TO C_{12} NORMAL ALKYL BENZENES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 21-1

Property data from the literature (1-23,25-36,38-59,75,95,97,139,157,158,174) are given in Table 21-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation and explosion limits in air are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 21-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 3% or less in most cases.

HEAT OF VAPORIZATION - Figure 21-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 21-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density for all compounds. The range of coverage applies to temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 3% in most cases.

SURFACE TENSION - Figure 21-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 5% or less in most cases.

HEAT CAPACITY - Figures 21-5 and 21-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 1% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data were correlated with a series expansion in temperature, Equation (1-6a). The results should be considered as rough estimates.

VISCOSITY - Figures 21-7 and 21-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 5% or less.

THERMAL CONDUCTIVITY - Figures 21-9 and 21-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 10% or less in most cases.

ENTHALPY OF FORMATION - Figure 21-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 21-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 21-1 Physical Properties

1. Name	Decylbenzene	Undecylbenzene	Dodecylbenzene
2. Formula	C16H26	C17H28	C18H30
3. Molecular Weight, g/mol	218.382	232.409	246.436
4. Critical Temperature, K	753.00	764.00	774.26
5. Critical Pressure, bar	17.70	16.72	15.789
6. Critical Volume, ml/mol	881.00	910.00	999.99
7. Critical Compressibility Factor	0.249	0.240	0.245
8. Acentric Factor	0.6812	0.7375	0.7855
9. Melting Point, K	258.77	268.00	275.93
10. Boiling Point @ 1 atm, K	571.04	586.40	600.76
11. Heat of Vaporization @ BP, kJ/kg	231.85	225.03	220.73
12. Density of Liquid @ 25 C, g/ml	0.852	0.852	0.851
13. Surface Tension @ 25 C, dynes/cm	30.49	30.93	31.29
14. Heat Capacity of Gas @ 25 C, J/g K	1.429	1.441	1.452
15. Heat Capacity of Liquid @ 25 C, J/g K	1.924	1.927	1.927
16. Viscosity of Gas @ 25 C, micropoise	45.42	44.56	43.98
17. Viscosity of Liquid @ 25 C, centipoise	3.457	4.152	4.818
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1098	0.1084	0.1067
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-137.83	-158.45	-179.11
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	194.08	202.47	210.79
22. Flash Point, K	380.37	418.00	413.71
23. Autoignition Temperature, K	------	------	------
24. Lower Explosion Limit in Air, vol %	0.5	0.5	0.4
25. Upper Explosion Limit in Air, vol %	------	4.9	------
26. Solubility in Water @ 25 C, ppm(wt)	------	------	------

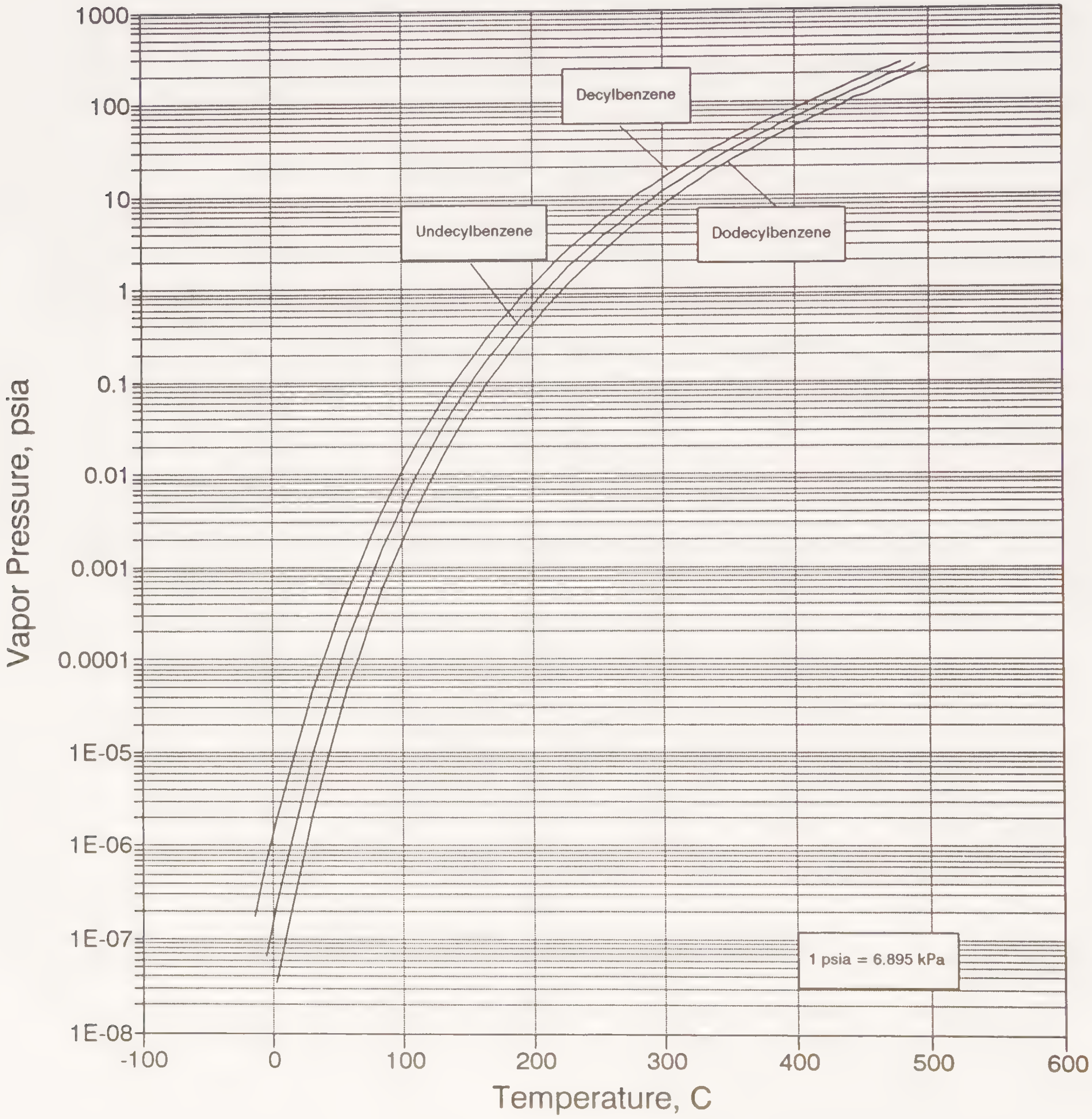

Figure 21-1 Vapor Pressure

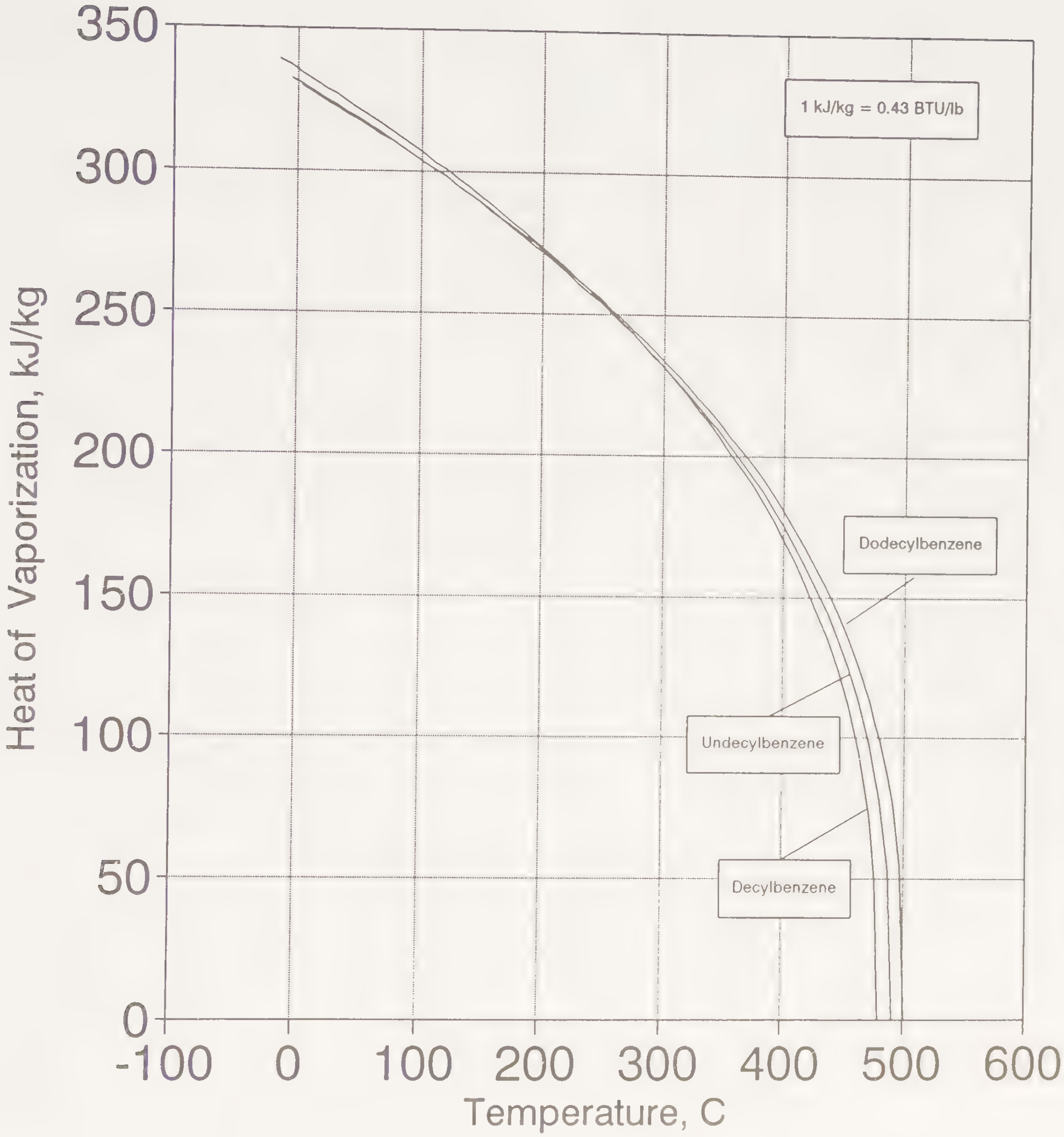

Figure 21-2 Heat of Vaporization

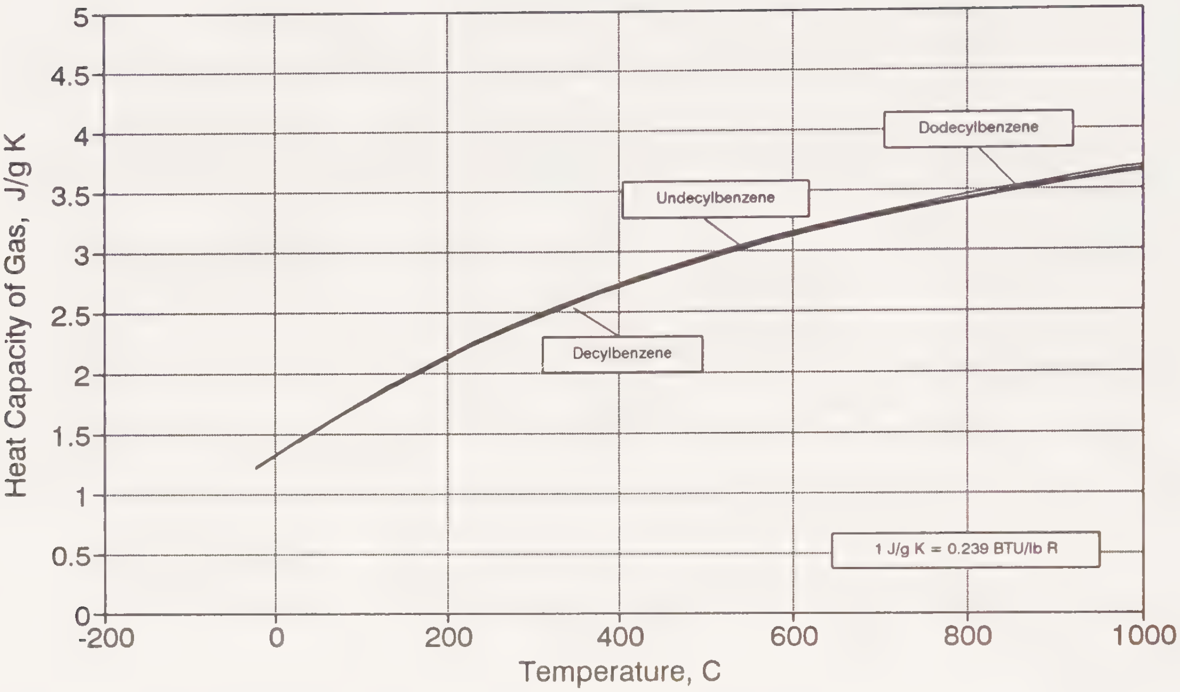

Figure 21-5 Heat Capacity of Gas

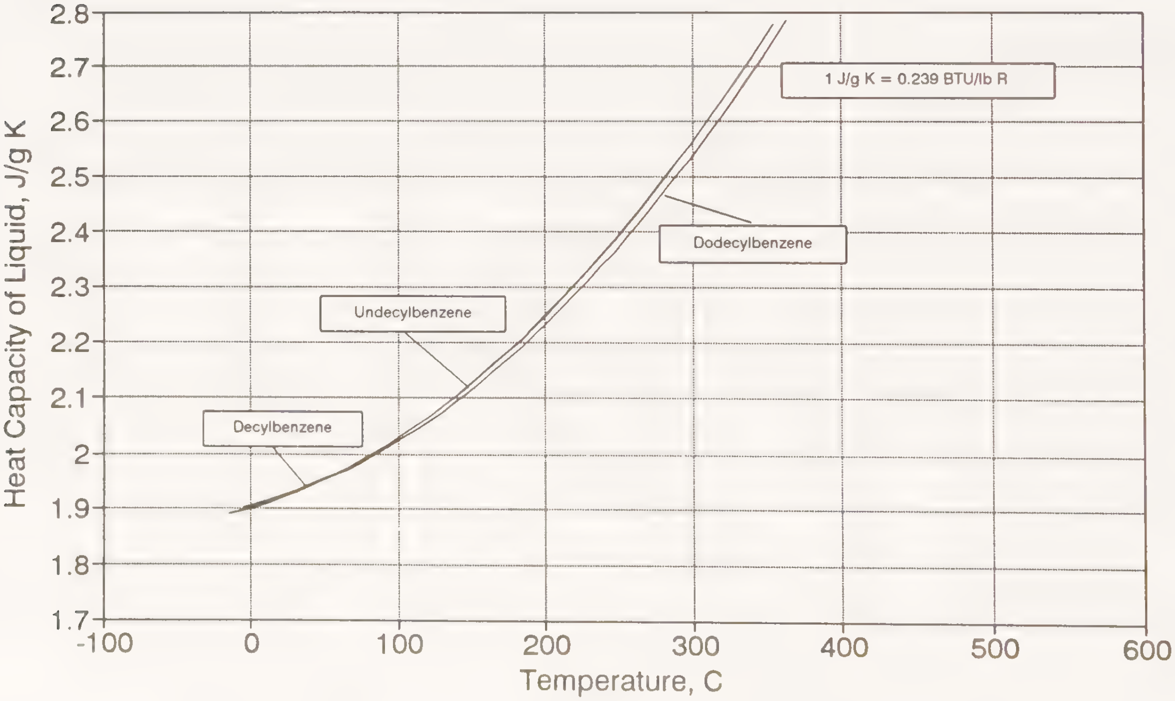

Figure 21-6 Heat Capacity of Liquid

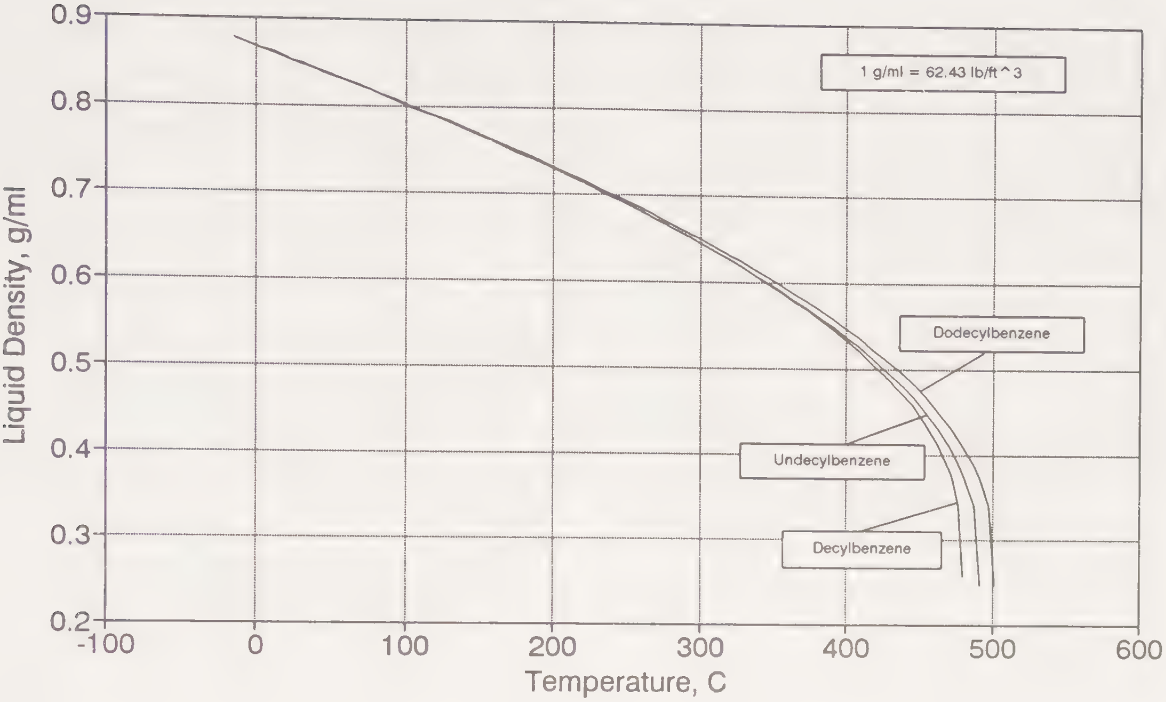

Figure 21-3 Liquid Density

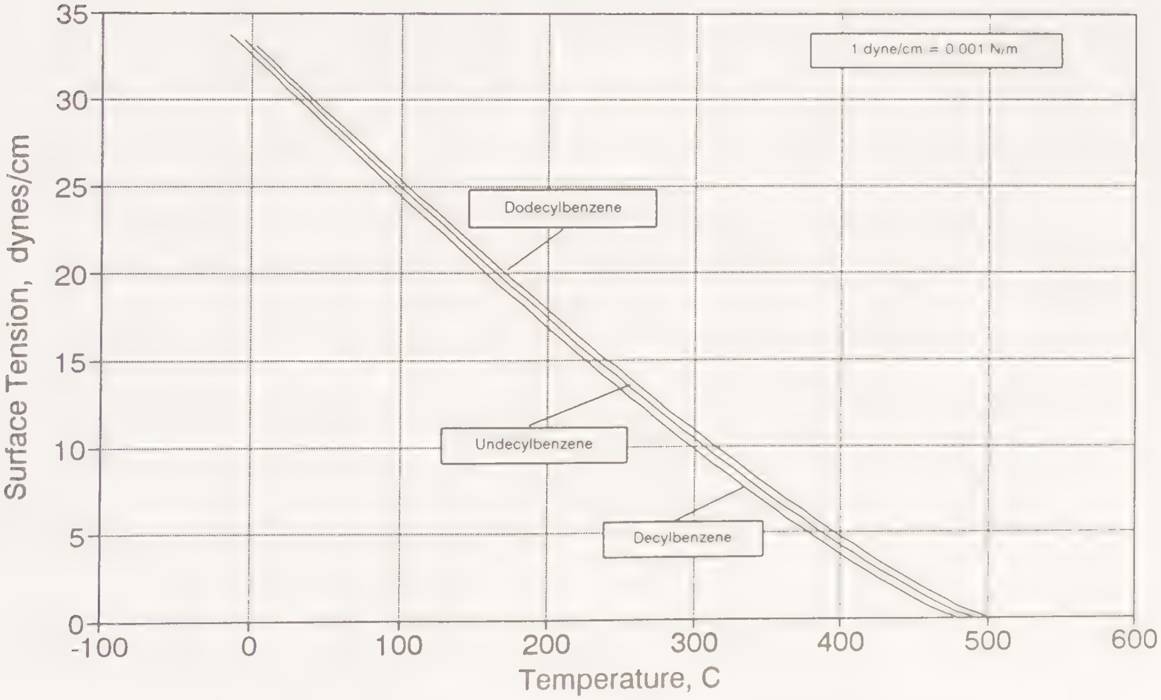

Figure 21-4 Surface Tension

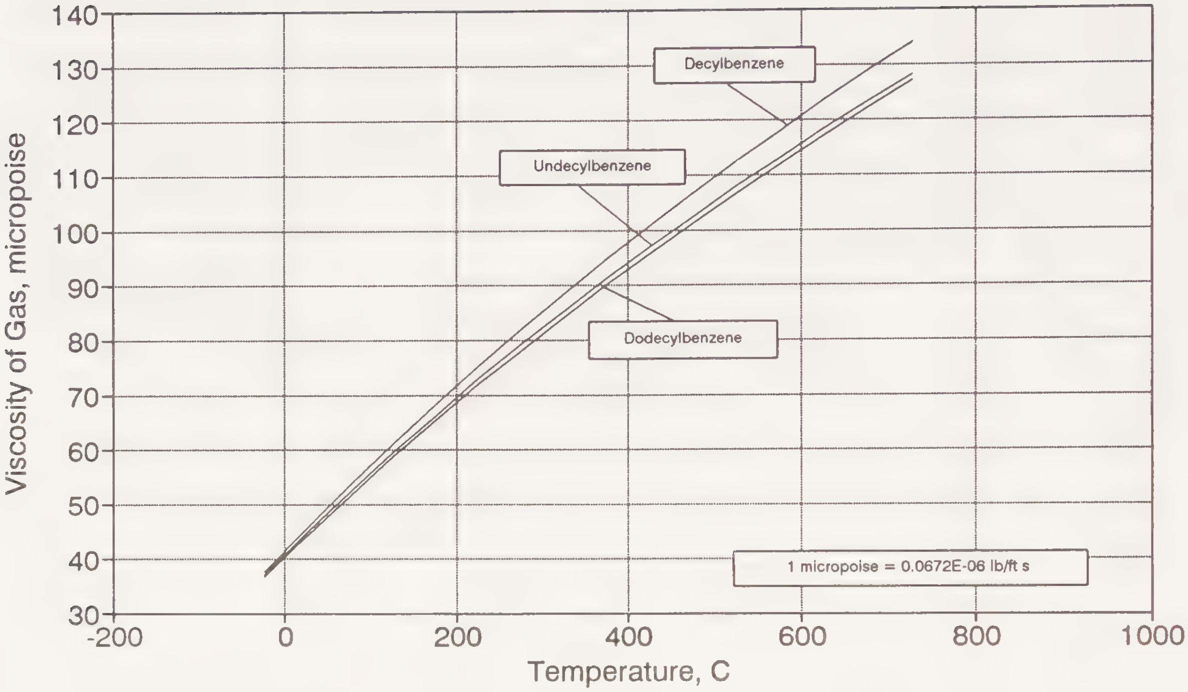

Figure 21-7 Viscosity of Gas

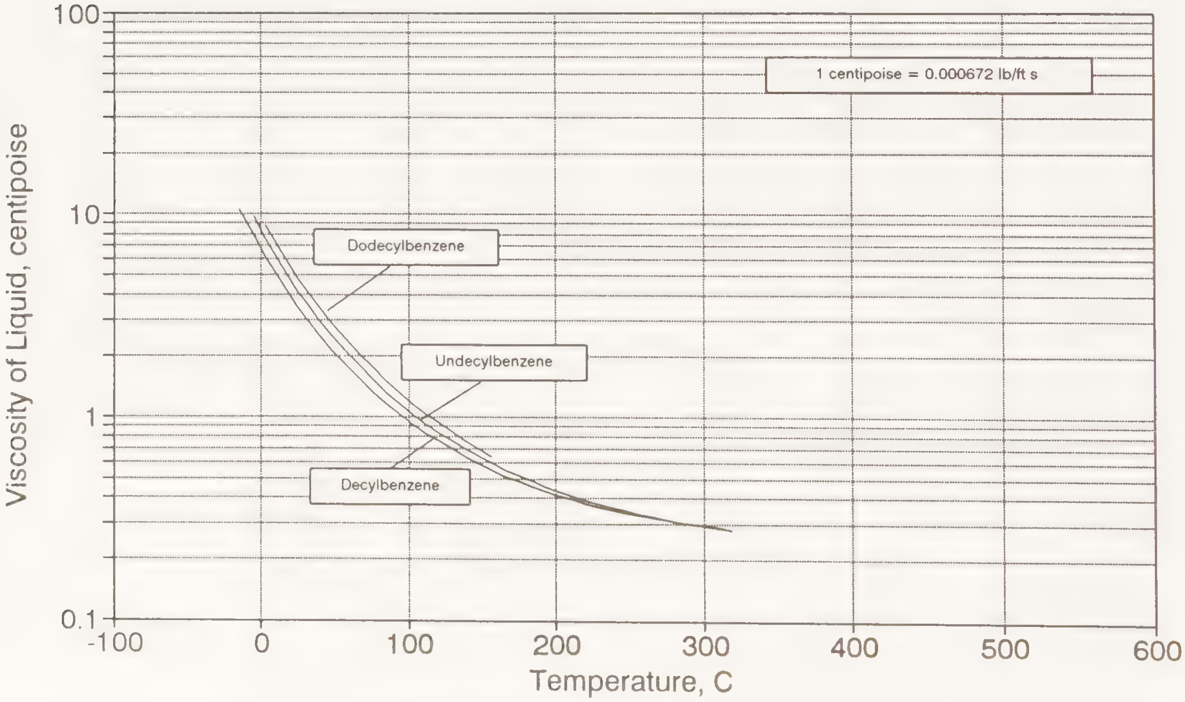

Figure 21-8 Viscosity of Liquid

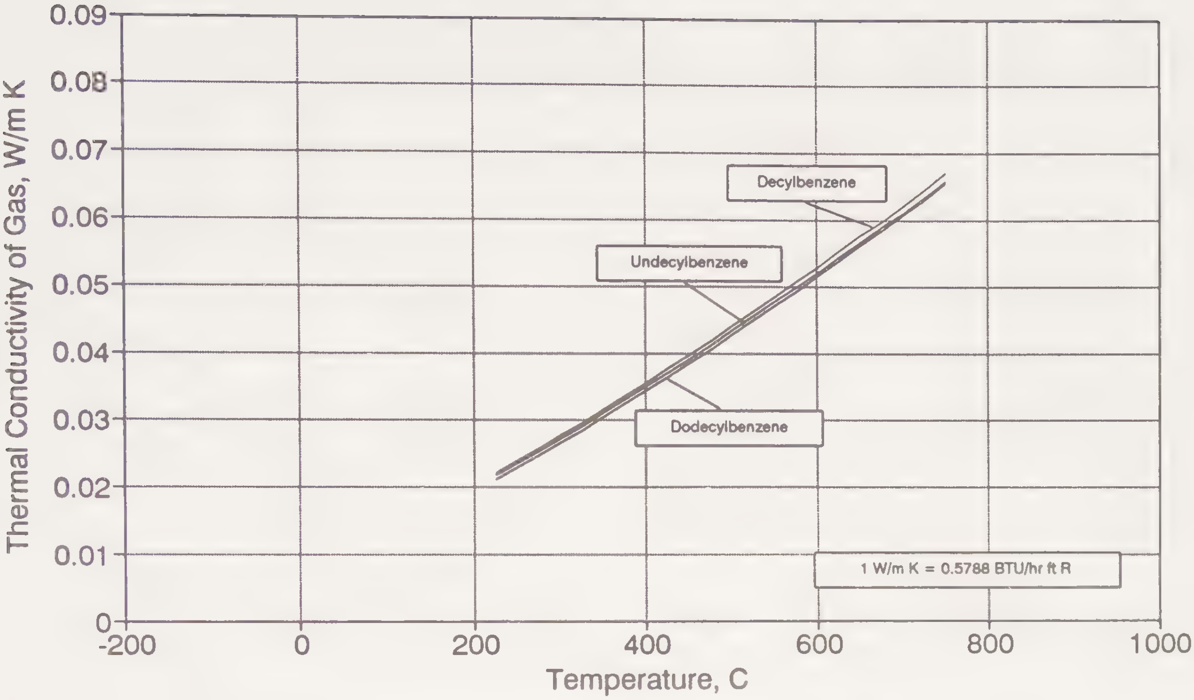

Figure 21-9 Thermal Conductivity of Gas

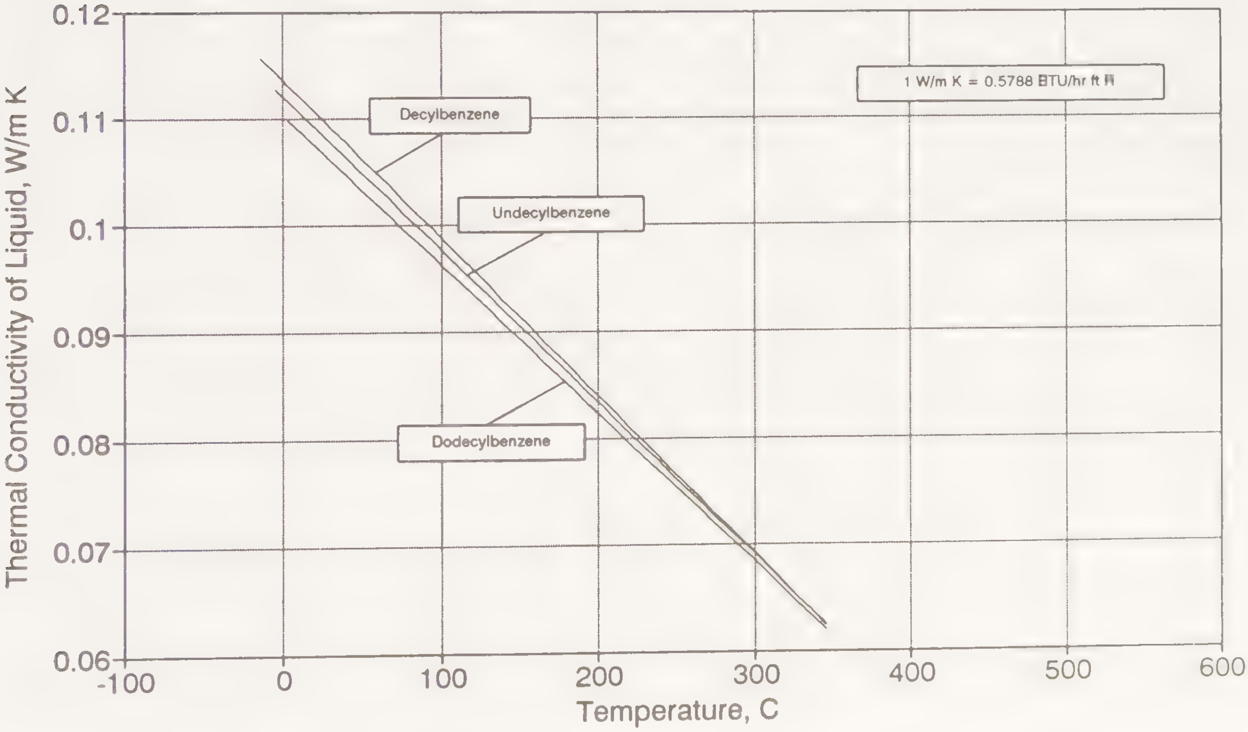

Figure 21-10 Thermal Conductivity of Liquid

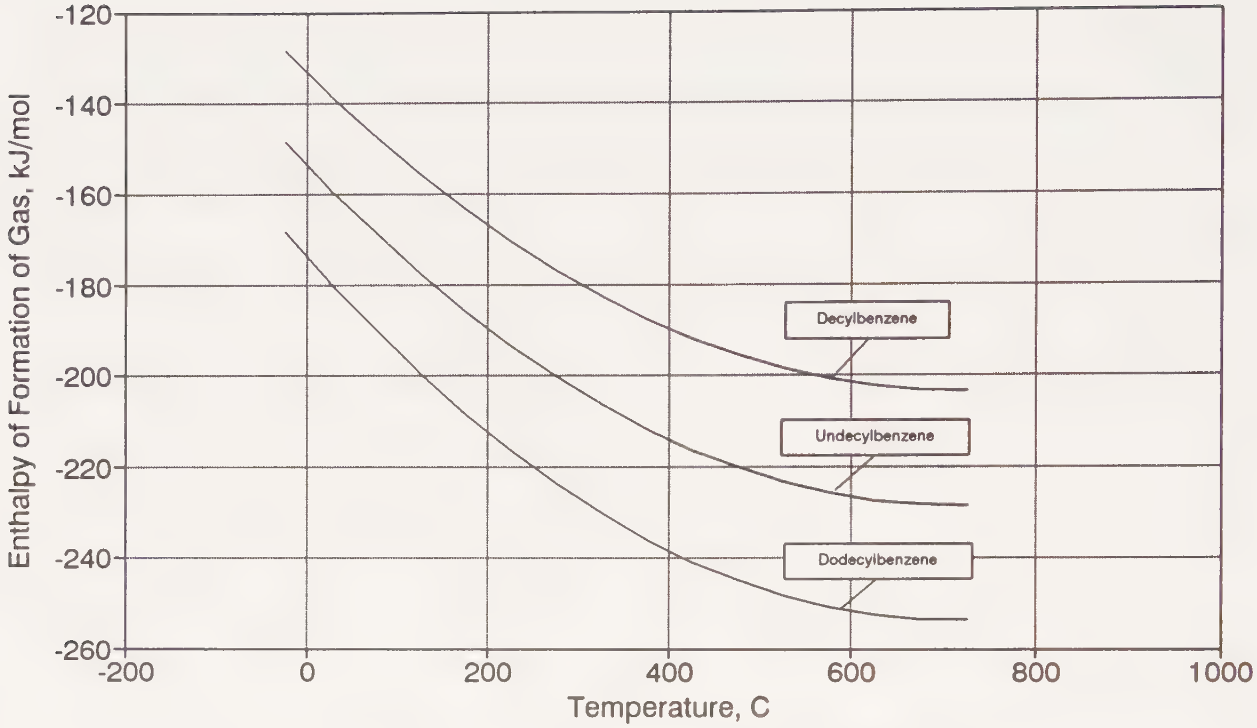

Figure 21-11 Enthalpy of Formation of Gas

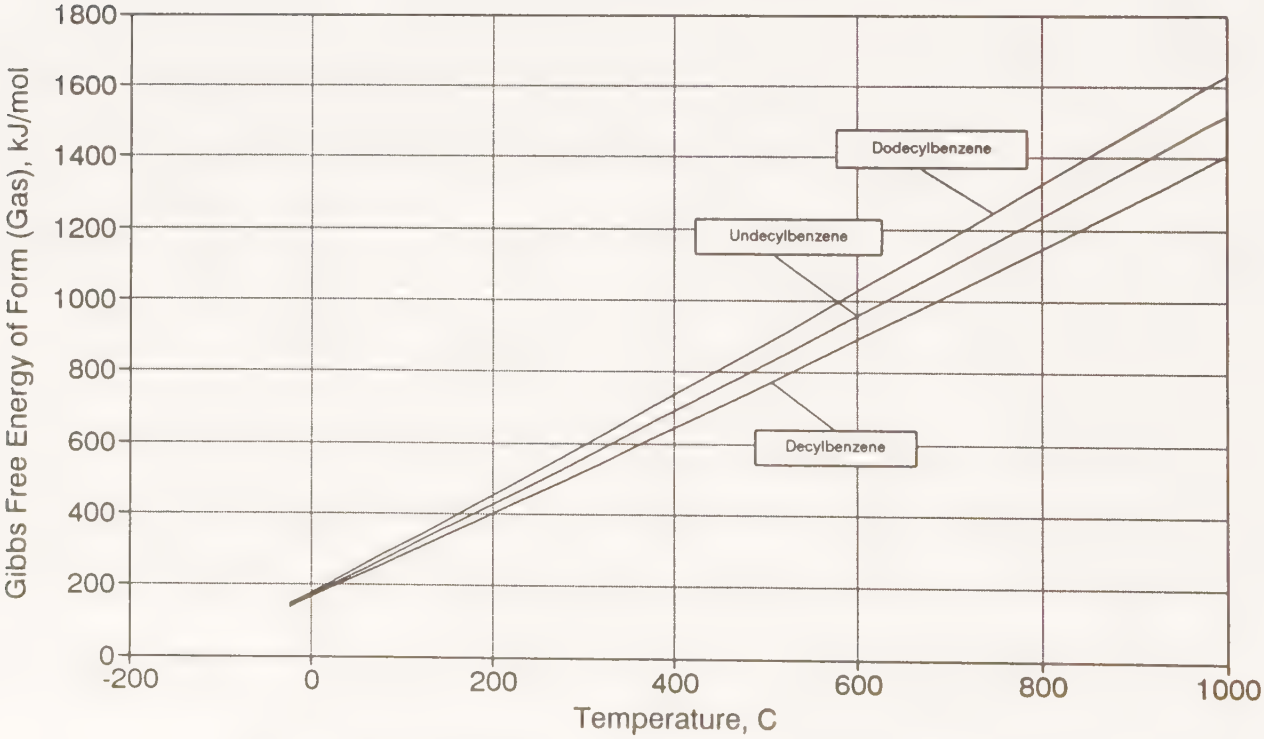

Figure 21-12 Gibbs Free Energy of Formation of Gas

Chapter 22

NAPHTHALENE AND DECAHYDRONAPHTHELENES

Robert W. Gallant and Carl L. Yaws

PHYSICAL PROPERTIES - Table 22-1

Property data from the literature (1-23,25-36,38-59,75,113,114,139,178-184) are given in Table 22-1. The critical constants were selected from the DIPPR project (5). Additional property data such as acentric factor, enthalpy of formation and explosion limits in air are also available. The DIPPR (Design Institute for Physical Property Research) project (5) and recent data compilations by Yaws and co-workers (44-59) were consulted extensively in preparing the tabulation.

VAPOR PRESSURE - Figure 22-1

Results from the DIPPR project (5) were selected for vapor pressure from very low temperatures to the critical point except. Correlation of data for vapor pressure as a function of temperature was accomplished using Equation (1-1). Results from this equation (Antoine-type with extended terms) are in favorable agreement with experimental data. Errors are about 5% or less in most cases.

HEAT OF VAPORIZATION - Figure 22-2

The data compilation of Yaws and co-workers (44,52) was selected for heat of vaporization for temperatures ranging from melting point to critical point. The Watson equation, Equation (1-2), was used for correlation of the data as a function of temperature. Reliability of results is good with errors of about 5% or less.

LIQUID DENSITY - Figure 22-3

Results from the data compilation of Yaws and co-workers (44,54) were selected for liquid density for all compounds except for 1-decene where more recent data (5) for critical constants was adopted. The range of coverage applies to temperatures at the melting point to higher temperatures up to the critical point. A modified Rackett equation, Equation (1-3a), was used for correlation of the data as a function of temperature. Results from the correlation are in favorable agreement with data. Deviations are less than 1% in most cases.

SURFACE TENSION - Figure 22-4

The data compilation of Yaws and co-workers (44,55) was selected for surface tension for temperatures from melting point to critical point. Using data from the literature, correlation for surface tension as a function of temperature over the full liquid range was achieved by the modified Othmer equation, Equation (1-4). Accuracy is good with errors being about 3% or less in most cases.

HEAT CAPACITY - Figures 22-5 and 22-6

Results from the data compilation of Yaws and co-workers (44) were selected for heat capacity of ideal gas. Correlation of data was accomplished using a series expansion in temperature, Equation (1-5). Results are in favorable agreement with data. Errors are about 3% or less in most cases.

Results from the data compilation of Yaws and co-workers (44,59) were selected for heat capacity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point. Data were correlated with a series expansion in temperature, Equation (1-6a). Results are in favorable agreement with data. Errors are about 5% or less using the correlation.

VISCOSITY - Figures 22-7 and 22-8

The DIPPR project (5) was selected for viscosity of gas. Data for gas viscosity as a function of temperature were correlated using Equation (1-7). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

The DIPPR project (5) was also selected for viscosity of liquid. Temperatures from below the boiling point to temperatures above the boiling point are covered for most of the compounds. Data for liquid viscosity as a function of temperature were correlated using the de Guzman - Andrade equation with extended terms, Equation (1-8). Correlation results and data are in favorable agreement with errors being about 10% or less.

THERMAL CONDUCTIVITY - Figures 22-9 and 22-10

Results from the DIPPR project (5) were selected for thermal conductivity of gas. Data for gas thermal conductivity as a function of temperature were correlated using the Equation (1-9). Reliability of results is good with errors of about 10% or less in most cases.

Results from the DIPPR project (5) were selected for thermal conductivity of liquid. The coverage applies to temperatures from below the boiling point to temperatures above the boiling point for most of the compounds. Data for liquid thermal conductivity as a function of temperature were correlated using a series expansion in temperature, Equation (1-10). Results are in favorable agreement with data. Errors are about 5% or less in most cases.

ENTHALPY OF FORMATION - Figure 22-11

The data compilation of Yaws and co-workers (44,45) was selected for enthalpy of formation of ideal gas. Data for enthalpy of formation of the ideal gas is a series expansion in temperature, Equation (1-11). Results from the correlation are in favorable agreement with data.

GIBB'S FREE ENERGY OF FORMATION - Figure 22-12

Results from the data compilation of Yaws and co-workers (44,46) were selected for Gibb's free energy of formation of ideal gas. Data for Gibb's free energy of formation of the ideal gas is a series expansion in temperature, Equation (1-12). Correlation results are in favorable agreement with data.

Table 22-1 Physical Properties

1. Name	Cis-Decahydronaphthalene	Trans-Decahydronaphthalene	Naphthalene
2. Formula	C10H18	C10H18	C10H8
3. Molecular Weight, g/mol	138.253	138.253	128.174
4. Critical Temperature, K	702.25	687.05	748.35
5. Critical Pressure, bar	32.424	28.371	40.51
6. Critical Volume, ml/mol	480.00	480.00	413.00
7. Critical Compressibility Factor	0.267	0.238	0.269
8. Acentric Factor	0.2942	0.2536	0.3019
9. Melting Point, K	230.20	242.79	353.43
10. Boiling Point @ 1 atm, K	468.97	460.46	491.14
11. Heat of Vaporization @ BP, kJ/kg	284.31	278.40	337.51
12. Density of Liquid @ 25 C, g/ml	0.871	0.888	------
13. Surface Tension @ 25 C, dynes/cm	31.70	29.43	------
14. Heat Capacity of Gas @ 25 C, J/g K	1.203	1.210	1.034
15. Heat Capacity of Liquid @ 25 C, J/g K	1.669	1.672	------
16. Viscosity of Gas @ 25 C, micropoise	------	------	------
17. Viscosity of Liquid @ 25 C, centipoise	3.074	1.949	------
18. Thermal Conductivity of Gas @ 25 C, W/m K	------	------	------
19. Thermal Conductivity of Liquid @ 25 C, W/m K	0.1127	0.1127	------
20. Enthalpy of Formation of Gas @ 25 C, kJ/mol	-169.35	-182.67	150.84
21. Gibbs Free Energy of Formation of Gas @ 25 C, kJ/mol	85.01	72.62	223.32
22. Flash Point, K	330.95	330.95	353.15
23. Autoignition Temperature, K	523.15	523.15	860.15
24. Lower Explosion Limit in Air, vol %	0.7	0.7	0.9
25. Upper Explosion Limit in Air, vol %	4.9	4.9	5.9
26. Solubility in Water @ 25 C, ppm(wt)	------	------	32.05

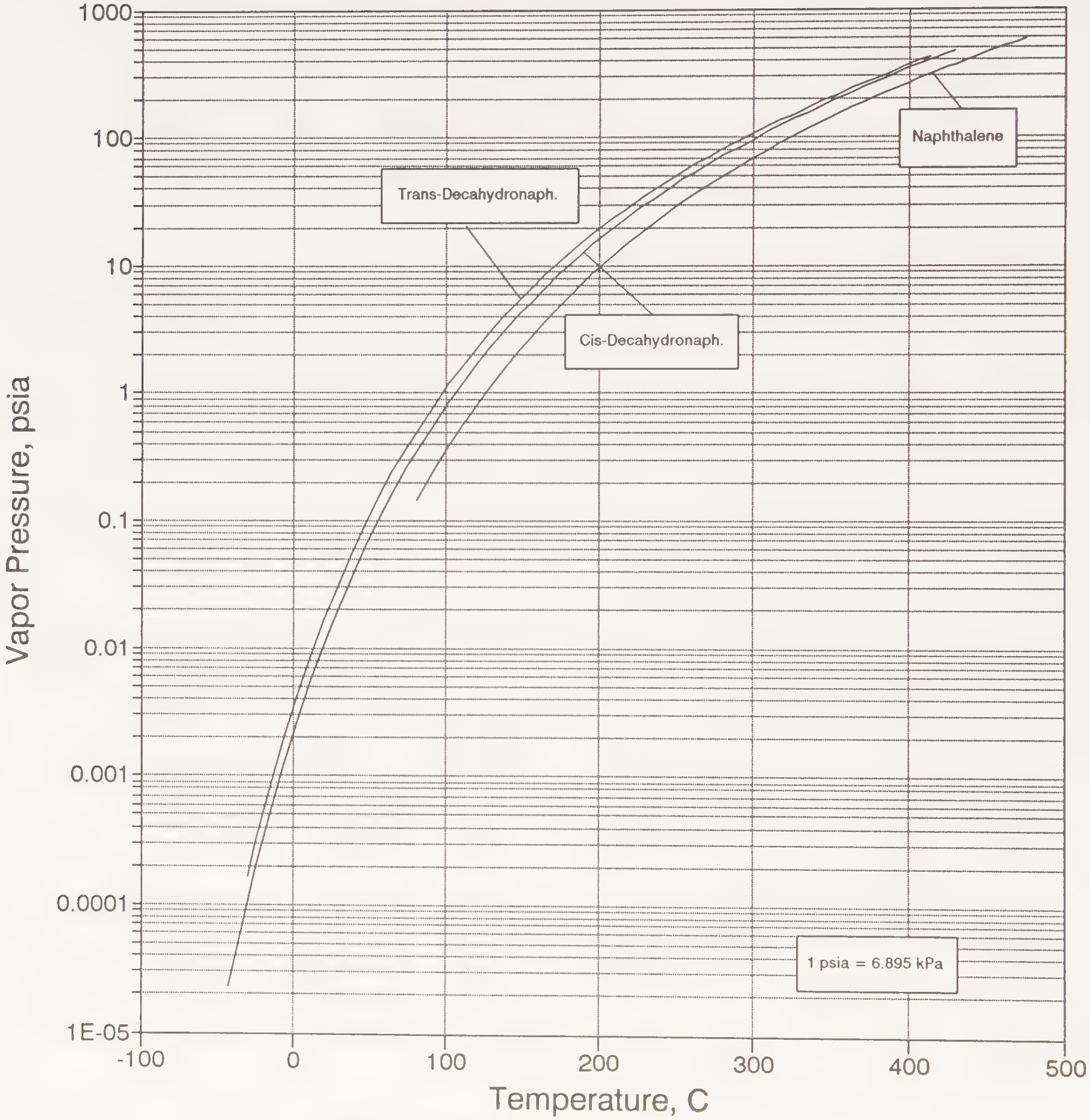

Figure 22-1 Vapor Pressure

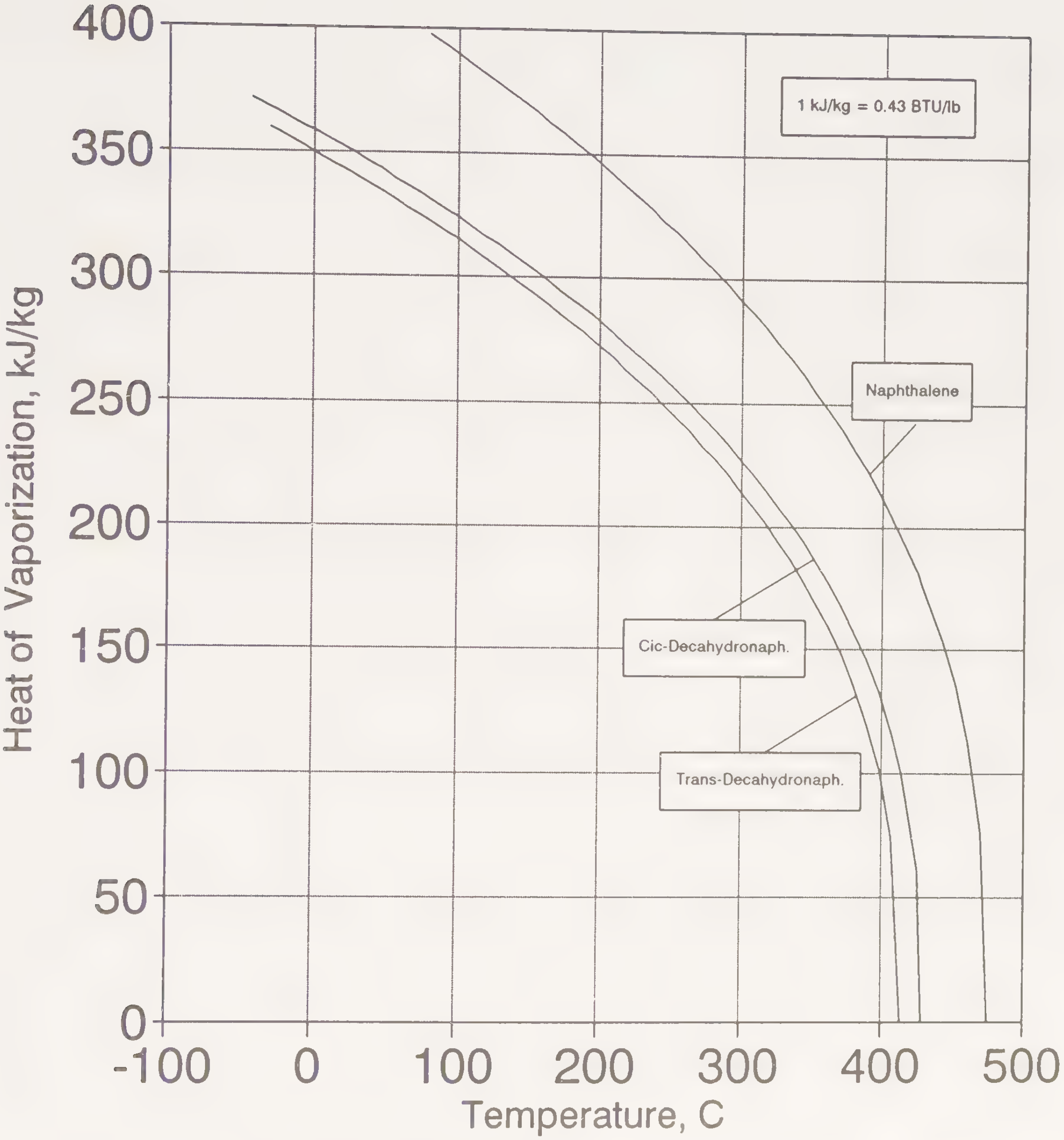

Figure 22-2 Heat of Vaporization

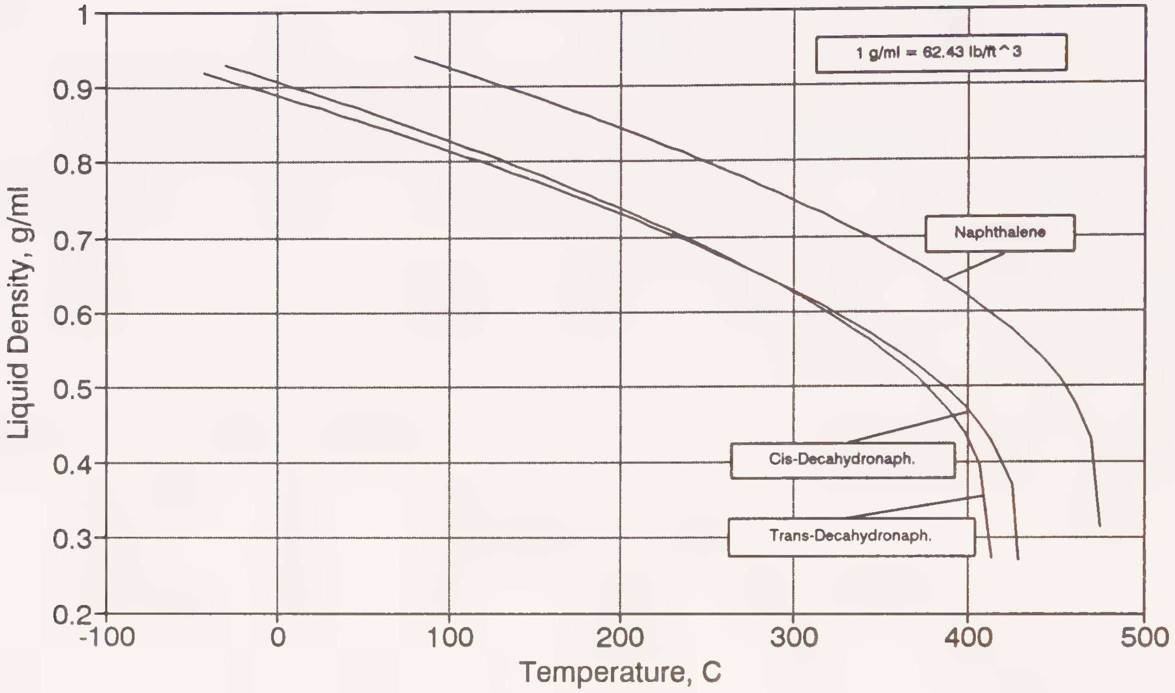

Figure 22-3 Liquid Density

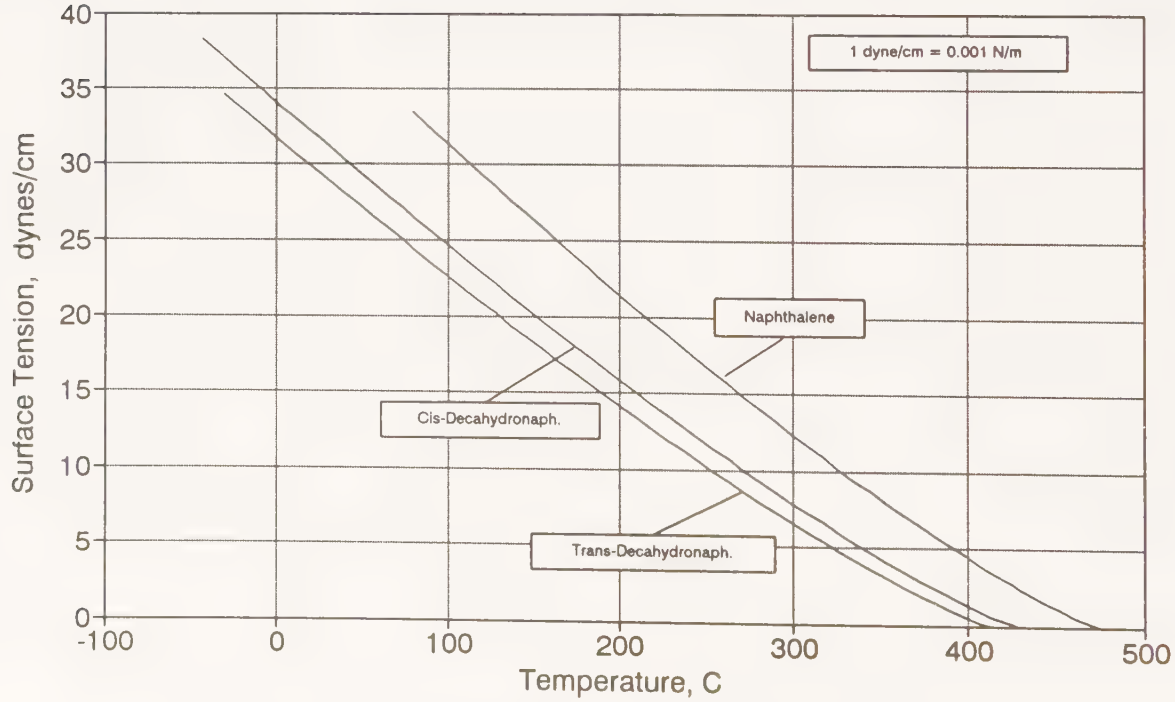

Figure 22-4 Surface Tension

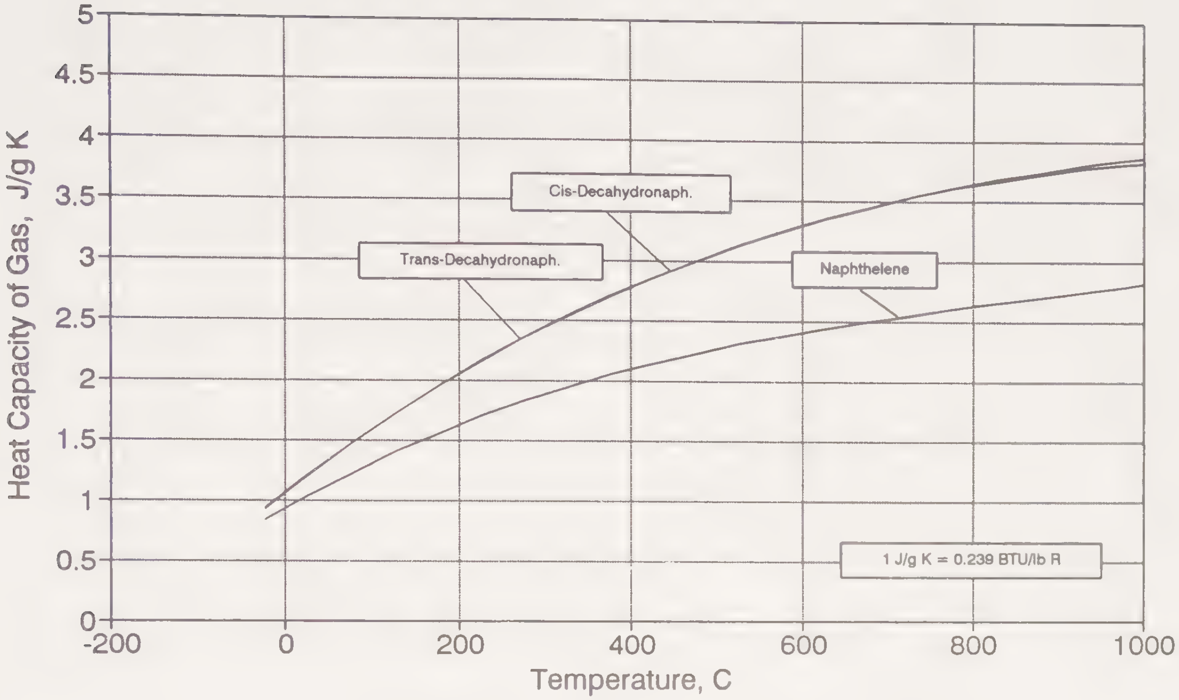

Figure 22-5 Heat Capacity of Gas

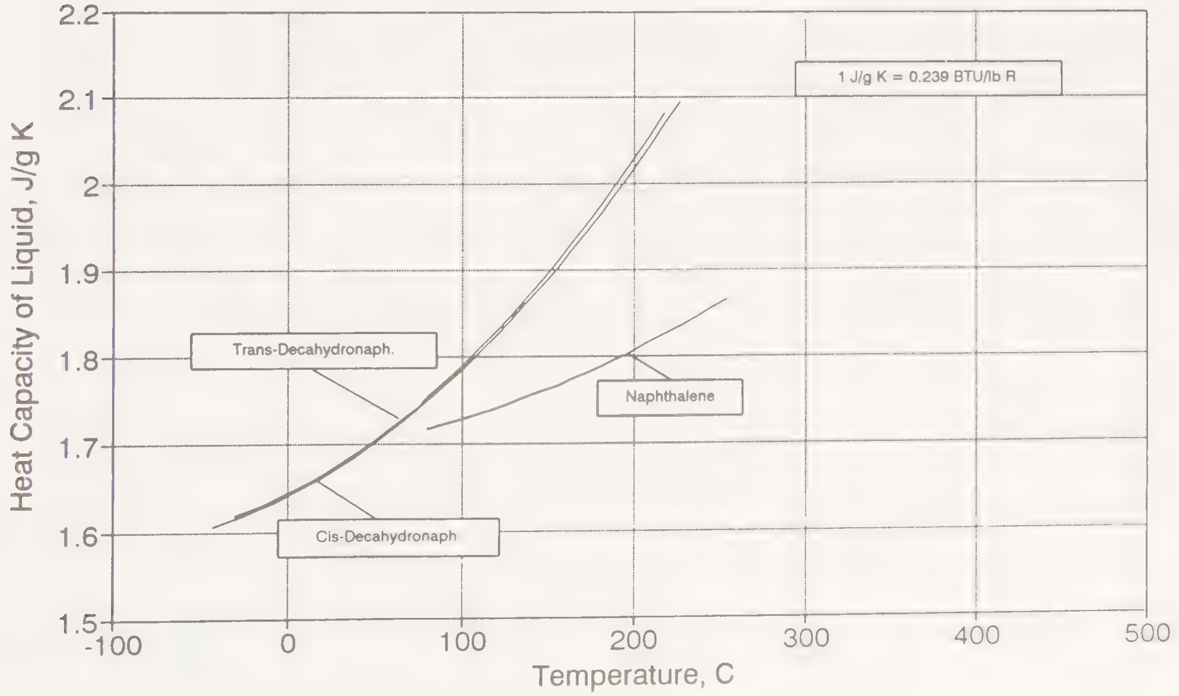

Figure 22-6 Heat Capacity of Liquid

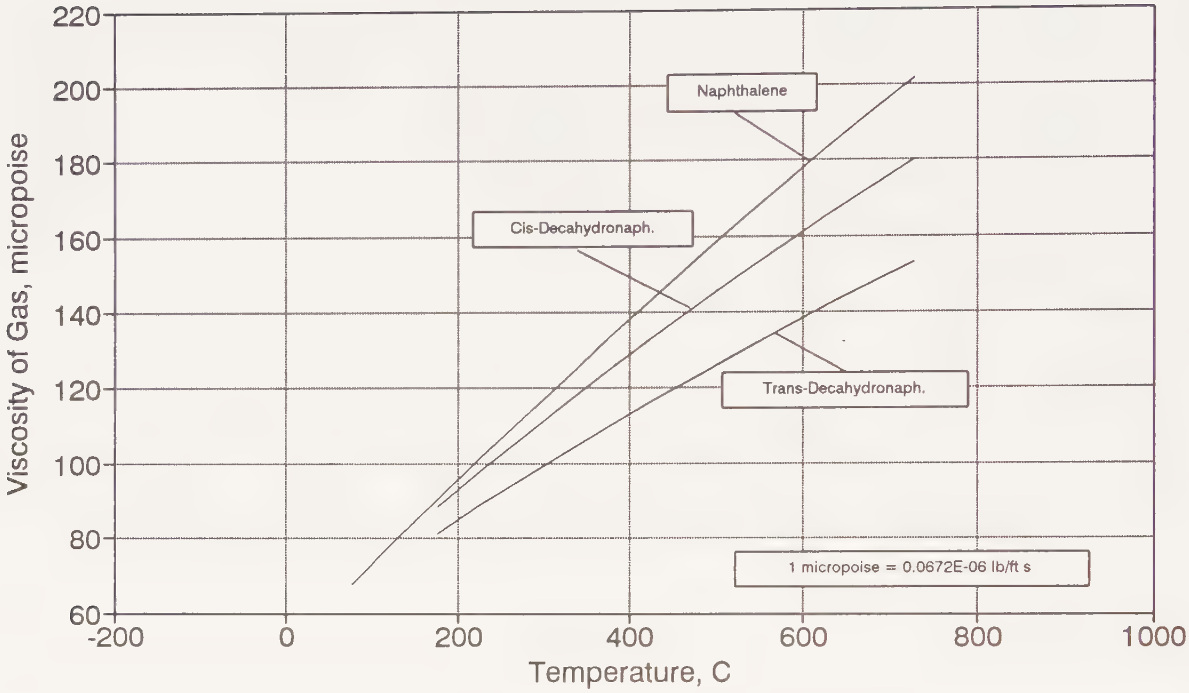

Figure 22-7 Viscosity of Gas

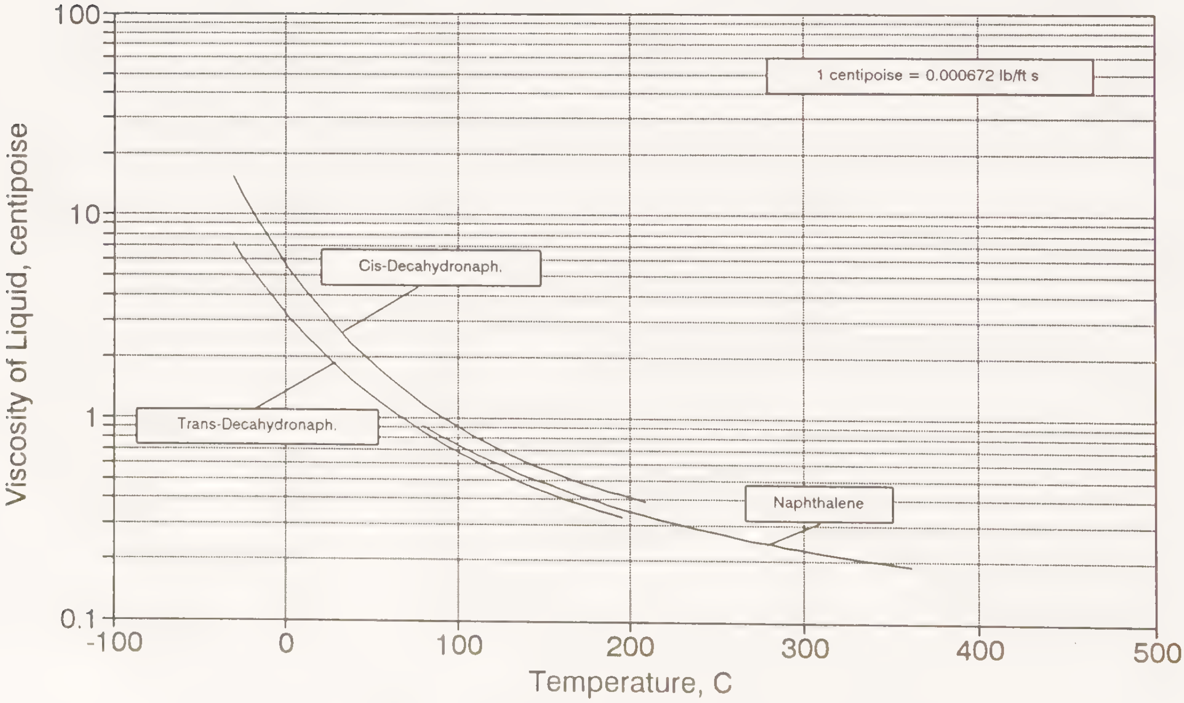

Figure 22-8 Viscosity of Liquid

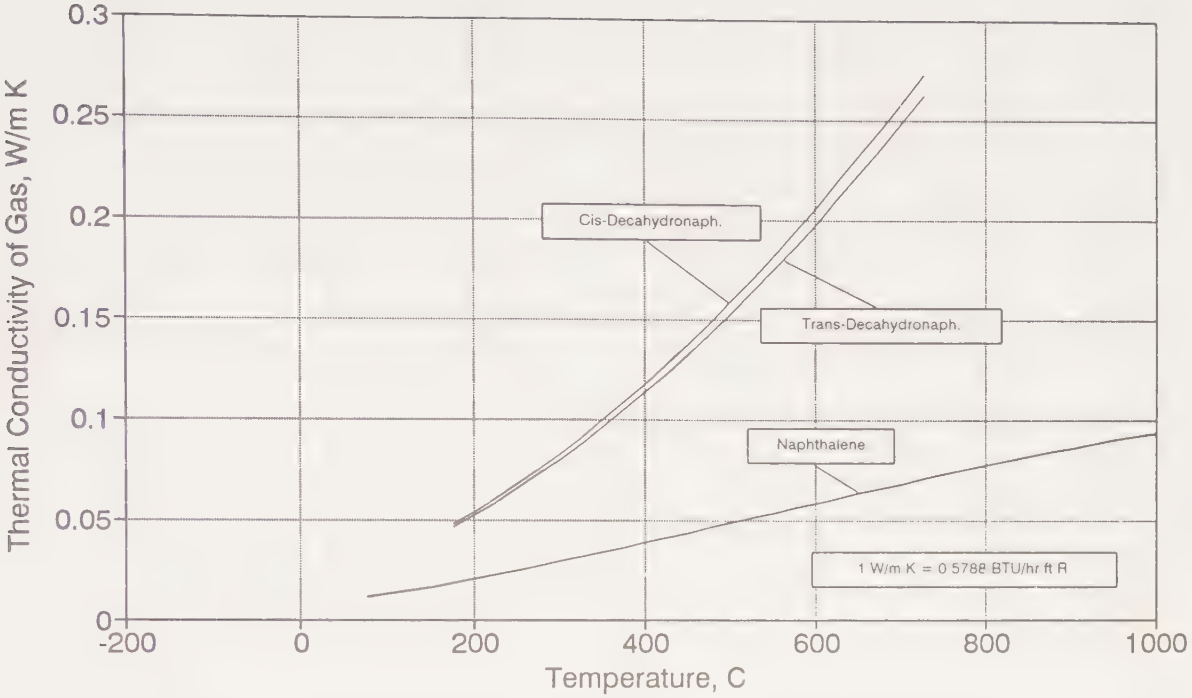

Figure 22-9 Thermal Conductivity of Gas

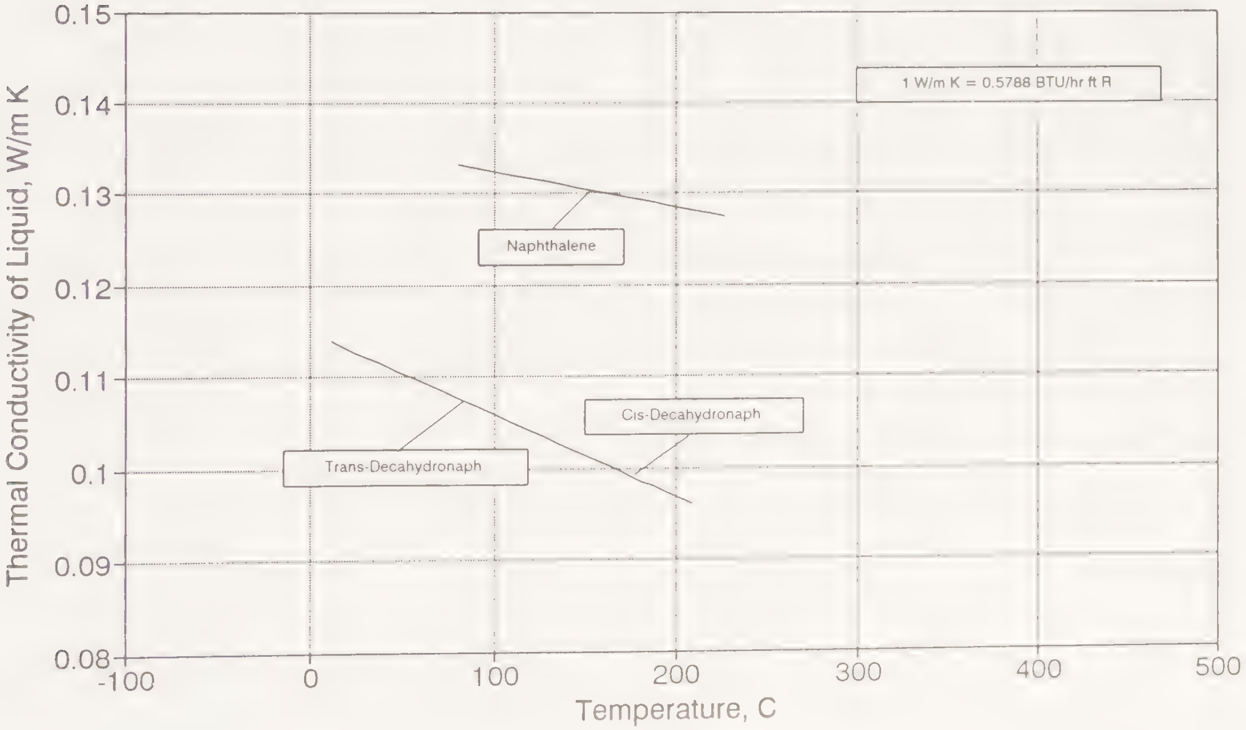

Figure 22-10 Thermal Conductivity of Liquid

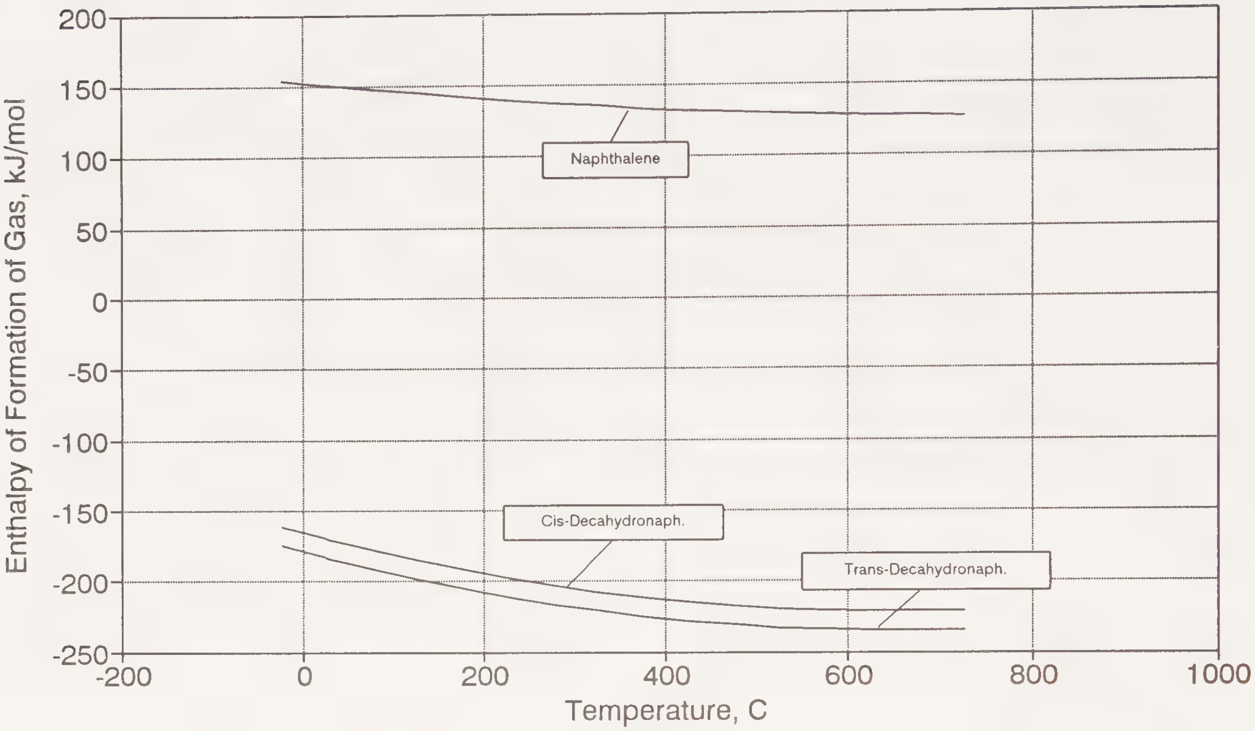

Figure 22-11 Enthalpy of Formation of Gas

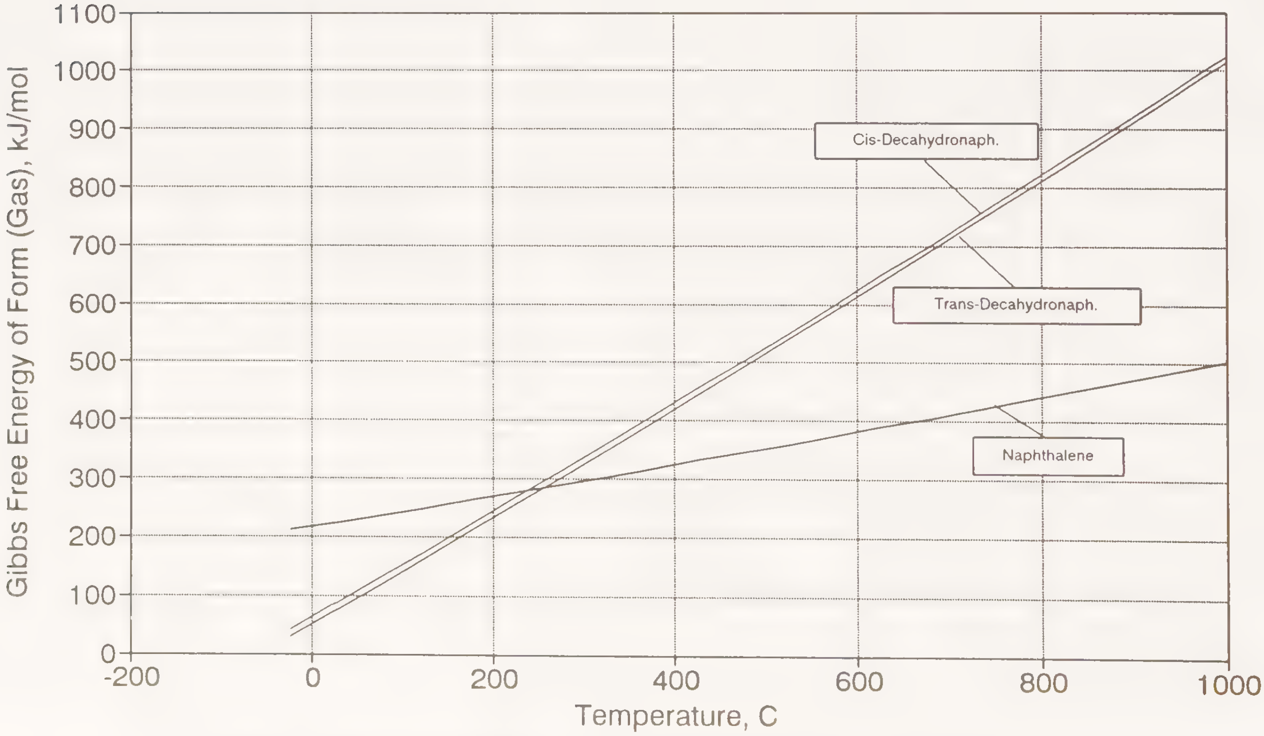

Figure 22-12 Gibbs Free Energy of Formation of Gas

REFERENCES

1. API Research Project No. 44, SELECTED VALUES OF PHYSICAL AND THERMODYNAMIC PROPERTIES OF HYDROCARBONS AND RELATED COMPOUNDS, Carnegie Press, Carnegie Institute of Technology, Pittsburgh, PA (1953).
2. SELECTED VALUES OF PROPERTIES OF HYDROCARBONS AND RELATED COMPOUNDS, Thermodynamics Research Center, TAMU, College Station, TX (1977, 1984).
3. SELECTED VALUES OF PROPERTIES OF CHEMICAL COMPOUNDS, Thermodynamics Research Center, TAMU, College Station, TX (1977, 1987).
4. TECHNICAL DATA BOOK - PETROLEUM REFINING, Vol. I and II, American Petroleum Institute, Washington, DC (1972, 1977, 1982).
5. Daubert, T. E. and R. P. Danner, DATA COMPILATION OF PROPERTIES OF PURE COMPOUNDS, Parts 1,2,3 and 4, Supplements 1 and 2, DIPPR Project, AIChE, New York, NY (1985-1992).
6. Ambrose, D., VAPOUR-LIQUID CRITICAL PROPERTIES, National Physical Laboratory, Teddington, England, NPL Report Chem 107 (Feb., 1980).
7. Simmrock, K. H., R. Janowsky and A. Ohnsorge, CRITICAL DATA OF PURE SUBSTANCES, Vol. II, Parts 1 and 2, Dechema Chemistry Data Series, 6000 Frankfurt/Main, Germany (1986).
8. INTERNATIONAL CRITICAL TABLES, McGraw-Hill, New York, NY (1926).
9. Maxwell, J. B., DATA BOOK ON HYDROCARBONS, D. Van Nostrand, Princeton. NJ (1958).
10. Egloff, G., PHYSICAL CONSTANTS OF HYDROCARBONS, Vols. 1-6, Reinhold Publishing Corp., New York, NY (1939-1947).
11. Din, F., THERMODYNAMIC FUNCTIONS OF GASES, Vols. 1-3, Butterworth Scientific Publications, London, England (1956-1962).
12. Edmister, W. C., APPLIED HYDROCARBON THERMODYNAMICS, Vols. 1 and 2, Vol 2, 2nd ed., Gulf Publishing Co., Houston, TX (1961, 1974, 1984).
13. Braker, W. and A. L. Mossman, MATHESON GAS DATA BOOK, 6th ed., Matheson Gas Products, Secaucaus, NJ (1980).
14. CRC HANDBOOK OF CHEMISTRY AND PHYSICS, 66th - 71th ed., CRC Press, Inc., Boca Raton, FL (1985-1990).
15. LANGE'S HANDBOOK OF CHEMISTRY, 13th ed., McGraw-Hill, New York, NY (1985).
16. PERRY'S CHEMICAL ENGINEERING HANDBOOK, 6th ed., McGraw-Hill, New York, NY (1984).
17. Kaye, G. W. C. and T. H. Laby, TABLES OF PHYSICAL AND CHEMICAL CONSTANTS, Longman Group Limited, London, England (1973).
18. Raznjevic, Kuzman, HANDBOOK OF THERMODYNAMIC TABLES AND CHARTS, Hemisphere Publishing Corporation, New York, NY (1976).
19. Driesbach, R. R., PHYSICAL PROPERTIES OF CHEMICAL COMPOUNDS, Vol. I (No. 15), Vol. II (No. 22), Vol. III (No. 29), Advances in Chemistry Series, American Chemical Society, Washington, DC (1955,1959,1961).
20. Vargaftik, N. B., TABLES ON THE THERMOPHYSICAL PROPERTIES OF LIQUIDS AND GASES, 2nd ed., English translation, Hemisphere Publishing Corporation, New York, NY (1975, 1983).
21. Timmermans, J., PHYSICO-CHEMICAL CONSTANTS OF PURE ORGANIC COMPOUNDS, Vol. 1 and 2, Elsevier, New York, NY (1950,1965).
22. Lyman, W. J., W. F. Reehl and D. H. Rosenblatt, HANDBOOK OF CHEMICAL PROPERTY ESTIMATION METHODS, McGraw-Hill, New York, NY (1982).
23. Bretsznajder, S., PREDICTION OF TRANSPORT AND OTHER PHYSICAL PROPRTIES OF FLUIDS, International Series of Monographs in Chemical Engineering, Vol. 2, Pergamon Press, Oxford, England (1971).
24. Horvath, A. L., PHYSICAL PROPERTIES OF INORGANIC COMPOUNDS, Crane, Russak &

Company, Inc., New York, NY (1975).

25. Reid, R. C., J. M. Prausnitz and B. E. Poling, THE PROPERTIES OF GASES AND LIQUIDS, 3rd ed. (R. C. Reid and T. K. Sherwood), 4th ed., McGraw-Hill, New York, NY (1977, 1987).
26. Kirk, R. E. and D. F. Othmer, editors, ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY, 3rd ed., Vols. 1-24, John Wiley and Sons, Inc., New York, NY (1978-1984).
27. Sax, N. I. and R. J. Lewis, Jr., HAWLEY'S CONDENSED CHEMICAL DICTIONARY, 11th ed., Van Nostrand Reinhold Co., New York, NY (1987).
28. Bondi, A., PHYSICAL PROPERTIES OF MOLECULAR CRYSTALS, LIQUIDS AND GLASSES, John Wiley, New York, NY (1968).
29. Beaton, C. F. and G. F. Hewitt, PHYSICAL PROPERTY DATA FOR THE DESIGN ENGINEER, Hemisphere Publishing Corporation, New York, NY (1989).
30. Gallant, R. W., PHYSICAL PROPERTIES OF HYDROCARBONS, Vols. 1 and 2, Vol 2, 2nd ed. (R. W. Gallant and J. M. Railey), Gulf Publishing Co., Houston, TX (1968, 1970, 1984).
31. Yaws, C. L., PHYSICAL PROPERTIES, McGraw-Hill, New York, NY (1977).
32. Zwolinski, B. J. and R. C. Wilhoit, VAPOR PRESSURES AND HEATS OF VAPORIZATION OF HYDROCARBONS AND RELATED COMPOUNDS, Thermodynamic Research Center, TAMU, College Station, TX (1971).
33. Boublick, T., V. Fried and E. Hala, THE VAPOUR PRESSURES OF PURE SUBSTANCES, 1st ed., 2nd ed., Elsevier, New York, NY (1975, 1984).
34. Ohe, S., COMPUTER AIDED DATA BOOK OF VAPOR PRESSURE, Data Book Publishing Company, Tokyo, Japan (1976).
35. Tryon, G. H., ed., FIRE PROTECTION HANDBOOK, 12th ed., National Fire Protection Association, Boston, Mass. (1962).
36. Jasper, J.J., J. Phys. Chem. Ref. Data, 1 (No.4), 841 (1972).
37. JANAF THERMOCHEMICAL TABLES, 2nd edition, NSRDS-NBS 37, U. S. Government Printing Office, Washington DC (1971).
38. Stull, D. R., E. F. Westrum, Jr., and G. C. Sinke, THE CHEMICAL THERMODYNAMICS OF ORGANIC COMPOUNDS, John Wiley and Sons, New York, NY (1969).
39. THERMOPHYSICAL PROPERTIES OF MATTER, 1st and 2nd eds., IFI/Plenum, New York, NY (1970-1976).
40. Ho, C. Y., P. E. Liley, T. Makita and Y. Tanaka, PROPERTIES OF INORGANIC AND ORGANIC FLUIDS, Hemisphere Publishing Corporation, New York, NY (1988).
41. Golubev, I. F., VISCOSITY OF GASES AND GAS MIXTURES, translated from Russian, US Dept. of Commerce, Springfield, VA (1970).
42. Stephan, K. and Lucas K., VISCOSITY OF DENSE FLUIDS, Plenum Press, New York, NY (1979).
43. Viswanath, D. S. and G. Natarajan, DATA BOOK ON THE VISCOSITY OF LIQUIDS, Hemisphere Publishing Corporation, New York, NY (1989).
44. Yaws, C. L., THERMODYNAMIC AND PHYSICAL PROPERTY DATA, Gulf Publishing Co., Houston, TX (1992).
45. Yaws, C. L. and P. Y. Chiang, "Enthalpy of Formation for 700 Major Organic Compounds," Chem. Eng., 95, 81 (Sept. 26, 1988).
46. Yaws, C. L. and P. Y. Chiang, "Find Favorable Reactions Faster," Hydrocarbon Processing, 67, 81 (Nov., 1988).
47. Yaws, C. L., D. Chen, H.-C. Yang, L. Tan and D. Nico, "Critical Properties of Chemicals", Hydrocarbon Processing, 68, 61 (July, 1989).
48. Yaws, C. L. and H.-C. Yang, "To Estimate Vapor Pressure Easily", Hydrocarbon Processing, 68, 65 (Oct.,1989).
49. Yaws, C. L., H.-C. Yang, Jack R. Hopper and Keith C. Hansen, "Hydrocarbons: Water Solubility Data", Chem. Eng., 97, 177 (April,1990).

50. Yaws, C. L., H.-C. Yang, Jack R. Hopper and Keith C. Hansen, "LETTERS: Hydrocarbons - Water Solubility Data", Chem. Eng., 97, 8 (May, 1990).
51. Yaws, C. L., H.-C. Yang, Jack R. Hopper and Keith C. Hansen, "Organic Chemicals: Water Solubility Data", Chem. Eng., 97, 115 (July, 1990).
52. Yaws, C. L., H.-C. Yang and William A. Cawley, "Predict Enthalpy of Vaporization", Hydrocarbon Processing, 69, 87 (June, 1990).
53. Yaws, C. L. and H.-C. Yang, "Water Solubility Data for Organic Compounds", Pollution Engineering, 22, 70 (Oct., 1990).
54. Yaws, C. L., H.-C. Yang, Jack R. Hopper and William A. Cawley, "An Equation for Liquid Density", Hydrocarbon Processing, 70, 103 (January, 1991).
55. Yaws, C. L., H.-C. Yang and Xiang Pan, "633 Organic Chemicals: Surface Tension Data", Chem. Eng., 98, 140 (March, 1991).
56. Yaws, C. L. and Xiang Pan, "New Correlation Calculates Reliable Paraffin Solubilities", Oil & Gas Journal, 89(14), 79 (April 8, 1991).
57. Yaws, C. L., Xiang Pan and D. G. Piper, Jr., "New Correlation Accurately Calculates Naphthene Water Solubilities", Oil & Gas Journal, 89(37), 86 (Sept. 16, 1991).
58. Yaws, C. L., H.-C. Yang and Xiang Pan, "Henry's Law Constants for 362 Organic Compounds in Water", Chem. Eng., 98, 179 (November, 1991).
59. Yaws, C. L., "Calculate Liquid Heat Capacity", Hydrocarbon Processing, 70, 73 (December, 1991).
60. Michels, A., T. Wassenaar and T. N. Zwretering, Physica, 18, 160 (1952).
61. Bryson, C. E., V. Cazcarra and L. Levenson, J. Chem. Eng. Data, 19(2), 107 (1974).
62. Hust, J. G. and R. B. Stewart, Natl. Bur. Stand. Tech. Note 202 (1963).
63. Boon, J. P., J. C. Legros and G. Thomas, Physica, 33, 547 (1967).
64. Rao, R. V. G. and K. N. Swamy, Z. Phys. Chem., Leipzig, 255(2), 300 (1974).
65. Herreman, W., W. Grevendork and A. DeBock, J. Chem. Phys., 53(1), 185 (1970).
66. Roder, H. M., R. D. McCarty and V. J. Johnson, Natl. Bur. Stand. Tech. Note 361 (1968).
67. Brower, G. T. and G. Thodos, J. Chem. Eng. Data, 13(2), 262 (1968).
68. Wagner, W., Cryogenics, 12(3), 214 (1972).
69. Rossini, F. D., D. D. Wagman, W. H. Evans, S. Levine and I. Jaffe, Natl. Bur. Stand. Circular No. 500 (1950).
70. McCarty, R. D. and L. A. Weber, Natl. Bur. Stand. Tech. Note 384 (1971).
71. Hanley, H. J. M. and J. F. Ely, J. Phys. Chem. Ref. Data, 2(4), 735 (1973).
72. Finke, H. L., M. E. Gross, G. Waddington and H. M. Huffman, J. Am. Chem. Soc., 78, 854 (1954).
73. Messerly, J. F., G. B. Gutherie, S. S. Todd and H. L. Finke, J. Chem. Eng. Data, 12, 338 (1967).
74. Zhdanov, A. G. and V. E. Lyusternik, Russ. J. Phys. Chem., 45(1), 113 (1971).
75. Chapman, S. and T. G. Cowling, The Mathematical Theory of Non Uniform Gases, Cambridge, England
76. Galloway, T. R. and B. H. Sage, J. Chem. Eng. Data, 12, 59 (1968).
77. Giller, E. B. and H. G. Drickames, Ind. Eng. Chem., 41, 2067 (1949).
78. Mustafaev, R. A., Teplofiz. Vys. Temp., 12(4), 883 (1974).
79. Mustafaev, R. A., Izv. Vyssh. Ucheb. Zhaved., Neft. Gaz., 16(11), 73 (1973).
80. Tarzimanov, A. A. and V. E. Mashirov, Teploenergetika, 14(12), 67 (1967).
81. Naziev, Y. M. and M. A. Aliev, Inz.-Fiz. Zh., 24(6), 1033 (1973).
82. Carmichael, L. T. and B. H. Sage, J. Chem. Eng. Data, 12(2), 210 (1967).
83. Briggs, D. K. H., Ind. Eng. Chem., 49, 418 (1957).
84. Rastorguev, Yu. L., G. F. Bogatov, and B. A. Grigorev, Izv. Vyssh. Ucheb. Zhaved., Neft. Gaz., 12(9), 69 (1969).
85. Sakiadis, B. C. and J. Coates, AIChE J., 3(1), 121 (1957).
86. Jobst, W., J. Heat Mass Transfer, 7, 725 (1964).
87. Mustafaev, R. A., Izv. Vyssh. Ucheb. Zhaved., Neft i Gaz., 15(7), 20 (1972).
88. Rastorguev, Yu. L., G. F. Bogatov, and B. A. Grigorev, Khim. i Tekhnol. Toppl. i Masel., 14(9), 31

(1969).

89. Willingham, C. B., W. J. Taylor, J. M. Pignocco and F. D. Rossini, J. Res. Natl. Bur. Std., A35, 219 (1945).
90. Svoboda, V., V. Charvatova, V. Majer and J. Pick, Coll. Czech. Commun., 46(12), 2983 (1981).
91. Geist, G. M. and M. R. Cannon, Ind. Eng. Chem., Anal. Ed., 18, 611 (1946).
92. Douslin, D. R. and H. M. Huffman, J. Am. Chem. Soc., 68, 173 (1946).
93. Wilhelm, E., J. P. Grolier and M. H. Karbalai Ghassemi, Thermochim. Acta., 28, 59 (1979).
94. Parks, G. S. and others, J. Am. Chem. Soc., 71, 3386 (1949).
95. Misic, D. and G. Thodos, AIChE J., 7, 264 (1961).
96. Smith, T. O. and others, Wright Air Development Center, Technical Report 59-327 (1962).
97. Pachaiyappan, V., S. H. Ibrahim and N. R. Kuloor, Chem. Eng., 74(4), 140 (1967).
98. Finke, H. L., J. F. Messerly and S. S. Todd, J. Phys. Chem., 69(6), 2094 (1965).
99. Mallan, G. M., M. S. Michaelian and F. J. Lockhart, J. Chem. Eng. Data, 17(4), 412 (1972).
100. Ishkin, I. P., Soviet Physics, 1, 2263 (1956).
101. Michels, A., T. Wassenaar, J. M. Levelt and W. DeGraff, Appl. Sci. Research, A4, 381 (1954).
102. Streng, A. G., J. Chem. Eng. Data, 6(3), 43 (1961).
103. Jenkins, A. C. and F. S. Dipaolo, J. Chem. Phys., 25(2), 296 (1956).
104. Hersh, C. K., A. W. Berger and J. R. C. Brown, Adv. in Chemistry Ser. No. 21, Am. Chem. Soc., Washington, DC (1959).
105. Riedel, L., Chem. Ing. Tech., 26, 83 (1954).
106. Wagman, D. D., W. H. Evans, V. B. Parker, I. Halow, S. M. Bailey and R. H. Schumm, Natl. Bur. Stand. Tech. Note 270-3 (1968).
107. Waterman, T. E., D. P. Kirsh and R. I. Brabets, J. Chem. Phys., 29(4), 905 (1958).
108. Haar, L. and J. S. Gallager, J. Phys. Chem. Ref. Data, 7(3), 635 (1978).
109. Zander, M. and W. Thomas, J. Chem. Eng. Data, 24(1), 1 (1979).
110. JANAF Thermochemical Tables, 1982 Supplement, J. Phys. Chem. Ref. Data, 11(3), 695 (1982).
111. Jamieson, D. T., J. B. Irving and J. S. Tudhope, LIQUID THERMAL CONDUCTIVITY - A DATA SURVEY TO 1973, Crown Publishing, Edinburg, England (1975).
112. McCarty, R. D., J. Phys. Chem. Ref. Data, 2(4), 923 (1973).
113. Touloukian, Y. S. and C. Y. Ho, PROPERTIES OF NONMETALLIC FLUID ELEMENTS, McGraw-Hill, New York, NY (1981).
114. Maitland, G. C. and E. B. Smith, J. Chem. Eng. Data, 17(2), 150 (1972).
115. Mann, D. B., Natl. Bur. Stand. Tech. Note 154A (1962).
116. Ho, C. Y., R. W. Powell and P. E. Liley, J. Phys. Chem. Ref. Data, 1(2), 279 (1972).
117. Saxena, S. C., High. Temp. Sci., 3, 168 (1971).
118. Jones, L. W., Int. J. Heat Mass Transfer, 10, 745 (1967).
119. Couch, E. J., K. A. Kobe and L. J. Hirth, J. Chem. Eng. Data, 6(2), 229 (1961).
120. Reamer, H. and B. Sage, Ind. Eng. Chem., 185 (Jan., 1952).
121. Cook, D., Trans. Faraday Soc., 49, 716 (1953).
122. Barin, I. and O. Knacke, THERMOCHEMICAL PROPERTIES OF INORGANIC SUBSTANCES, Springer-Verlag, Berlin, Germany (1973).
123. Richter, G. N. and B. H. Sage, J. Chem. Eng. Data, 8(2), 221 (1963).
124. Schaefer, C. A. and G. Thodos, AIChE J., 5(3), 367 (1959).
125. Hampel, C. A., THE ENCYCLOPEDIA OF CHEMICAL ELEMENTS, Reinhold, New York, NY (1968).
126. Scott, R. B., CYROGENIC ENGINEERING, Van Nostrand, New York, NY (1959).
127. Vance, R. W. and W. M. Duke, APPLIED CYROGENIC ENGINEERING, John Wiley and Sons, Inc., New York, NY (1962).
128. Roder, H. M. and others, Natl. Bur. Stand. Tech. Note 625 (1972).
129. COMPREHENSIVE INORGANIC CHEMISTRY, Vol. I-VIII, Van Nostrand, New York, NY (1953-

1966).

130. Angus, S. and B. Armstrong, editors, INTERNATIONAL TABLES OF THE FLUID STATE - ARGON, Butterworths, London, England (1971).
131. Saji, Y. and S. Kobayashi, Cryogenics, 4, 136 (1964).
132. Baroncini, C. and others, Int. J. Thermophysics, 2(1), 21 (1981).
133. Kestin, J. and others, J. Phys. Chem. Ref. Data, 13(1), 229 (1984).
134. Forster, S., Cryogenics, 3, 176 (1963).
135. Hyne, R. A. and P. F. Tiley, J. Chem. Soc., 2348 (1961).
136. Hu, J., D. White and H. L. Johnston, J. Am. Chem. Soc., 15, 5642 (1953).
137. Gray, D. E., AMERICAN INSTITUTE OF PHYSICS HANDBOOK, 3rd ed., McGraw-Hill, New York, NY (1972).
138. Lindenberg, A. B., Comptes Rend. Acad. Sci. Paris, 273, 1017 (1971).
139. Clapeyron, J., L'ecole Polytechnique, 14(23), 153 (1834).
140. Giauque, W. F. and T. M. Powell, J. Am. Chem. Soc., 61, 1970 (1939).
141. Misra, S. C. and K. N. Parida, Ind. J. Pure Appl. Phys., 7, 772 (1969).
142. Eucken. A. and E. Karwat, Z. Phys. Chem., 112, 467 (1924).
143. Prydz, R. and J. Stratz, J. Res. Nat. Bur. Stand., 74A, 747 (1970).
144. Hanley, H. J. M. and R. Prydz, J. Phys. Chem. Ref. Data, 1(4), 1101 (1972).
145. White, D., J. H. Hu and H. L. Johnston, J. Am. Chem. Soc., 76, 2584 (1954).
146. Stull, D. R. and G. C. Sinke, THERMODYNAMIC PROPERTIES OF THE ELEMENTS, Advances in Chemistry Series 18, American Chemical Society, Washington, DC (1956).
147. Samsonov, G. V., HANDBOOK OF THE PHYSICO-CHEMICAL PROPERTIES OF THE ELEMENTS, Plenum, Washington, DC (1978).
148. McBride, B. J. and others, THERMODYNAMIC PROPERTIES TO 6000 K FOR 210 SUBSTANCES INVOLVING THE FIRST 18 ELEMENTS, NASA, Washington, DC (1963).
149. Robinson, D. B. and N. H. Senturk, J. Chem. Thermo., 11, 461 (1979).
150. Kemp, J. D. and W. F. Giauque, J. Am. Chem. Soc., 59, 79 (1937).
151. Sage, B. H. and W. N. Lacey, Monograph on API Res. Proj. 37, American Petroleum Institute, New York, NY (1955).
152. Stiel, L. T. and G. Thodos, J. Chem. Eng. Data, 10, 266 (1964).
153. Thomas, L. H., J. Chem. Soc., 573 (1946).
154. Missenard, A., Comptes Rendus, 260(5), 5521 (1965).
155. Hughes, E. E. and S. G. Lias, Natl. Bur. Stand. Tech. Note 70 (1960).
156. Macknick, A. B. and J. M. Prausnitz, J. Chem. Eng. Data, 24(3), 175 (1979).
157. Camin, D. L. and others, J. Phys. Chem., 59, 440 (1954).
158. Lee, B. I. and M. G. Kesler, AIChE J., 21(3), 510 (1975).
159. Matthews, M. A. and others, J. Chem. Eng. Data, 32, 317 (1987).
160. Mustafaev, R. A., Inz.-Fiz. Zhum., 24, 663 (1973).
161. Naziev, Y. M., Izv. Vyssh. Zaved., Neft i Gaz, 16(7), 73 (1973).
162. Powell, R. M. and A. R. Challoner, Ind. Eng. Chem., 53, 581 (1961).
163. Ziebland, H. and J. E. Patient, J. Chem. Eng. Data, 7(4), 530 (1962).
164. Roy, D. and G. Thodos, Ind. Eng. Chem. Fundam., 7, 529 (1968).
165. Roy, D. and G. Thodos, Ind. Eng. Chem. Fundam., 9, 71 (1970).
166. VanVelzen, D., Lopes, R. Cardozo and H. Langenkamp, EUR 4735e, Commission of European Communities, Luxembourg (1972).
167. Schiessler, R. W. and F. C. Whitmore, Ind. Eng. Chem., 47, 1660 (1955).
168. Rastorguev, Yu. L. and others, Khim. i. Teknol. Topl. i. Masl., 9, 54 (1974).
169. Forziati, A. D., D. L. Camin and F. D. Rossini, J. Res. Natl. Bur. Std., 45, 406 (1950).
170. McCullough, J. P. and others, J. Phys. Chem., 61, 289 (1957).
171. Wright, F. J., J. Chem. Eng. Data, 6, 454 (1961).

172. Mukhamedzyanov, G. Kh. and A. G. Usmanov, Izv. Vyssh. Ucheb. Zaved. Priborostr., 12(10), 119 (1969).
173. Standard Oil Company (Indiana), Whiting Lab. Report No. F45-9 (1945).
174. Douslin, D. R. and H. M. Huffman, J. Am. Chem. Soc., 68, 1074 (1946).
175. McCann, G. W., M. S. Thesis, The Pennsylvania State University (1982).
176. Conolly, T. J., B. H. Sage and W. N. Lacey, Ind. Eng. Chem., 43, 946 (1951).
177. Messerly, J. F., S. S. Todd, and H. L. Hinke, J. Phys. Chem., 69, 353 (1965).
178. American Petroleum Institute, API Publication 706, Washington, DC (Oct., 1978).
179. Fowler, L. and others, J. Chem. Eng. Data, 13(2), 209 (1968).
180. American Petroleum Institute, API Publication 707, Washington, DC (Oct., 1978).
181. McCullough, J. P. and others, J. Phys. Chem., 61, 1105 (1957).
182. DeKruif, C. G. and others, J. Chem. Thermo., 13, 1081 (1981).
183. Lielmezs, J. and others, Thermochim. Acta, 47, 287 (1981).
184. Bachmann, R., Warme-u. Stoffubert., 2(3), 129 (1969).
185. Svoboda, V., V. Charvatova, V. Majer and V. Hynek, Coll. Czech. Chem. Comm., 47(2), 543 (1981).
186. Messerly, J. F. and others, J. Phys. Chem., 69, 12 (1965).
187. Rastorguev, Yu. L. and V. V. Pugach, Izv. Vyssh. Ucheb. Zhaved., Neft i Gaz., 13(8), 69 (1970).
188. Othmer, D. F. and E. Yu, Ind. Eng. Chem., 60, 22 (1968).
189. Allemand, N. and others, Thermochim. Acta, 105, 79 (1986).
190. Groh, J., M. S. Ree and T. H. Eyring, Proc. Nat. Acad. Sci., 54, 1004 (1965).
191. Kobe, K. A. and E. G. Long, Petrol. Refiner, 29(2),124 (1950).
192. Sax, N. I. and R. J. Lewis, DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS, 7th ed., Van Nostrand Reinhold, New York, NY (1989).
193. Lewis, R. J., HAZARDOUS CHEMICALS DESK REFERENCE, Van Nostrand Reinhold, New York, NY (1990).

Appendix A

CONVERSION TABLES

1. **Temperature**
   To convert from Centigrade to:
   - Kelvin, add 273.15
   - Rankine, multiply Kelvin by 1.8
   - Fahrenheit, multiply Centigrade by 1.8 and add 32

2. **Pressure**
   To convert from psia to:
   - kPa, multiply by 6.895
   - psig, subtract 14.7
   - mm Hg, multiply by 51.7
   - atmospheres, divide by 14.7
   - bars, divide by 14.89

3. **Heat of Vaporization**
   To convert from kJ/kg to:
   - BTU/lb, multiply by 0.43
   - cal/gram, multiply by 0.239

4. **Density**
   To convert from g/ml to:
   - lb/ft^3, multiply by 62.43
   - lb/gallon, multiply by 8.345

5. **Surface Tension**
   To convert from dynes/cm to:
   - N/m, multiply by 0.001

6. **Heat Capacity**
   To convert from J/g K to:
   - BTU/lb R, multiply by 0.239
   - cal/gram K, multiply by 0.239

7. **Viscosity**
   To convert from micropoise to:
   - lb/ft s, multiply by 0.0672E-06
   - centipoise, multiply by 1.0E-04
   - poise, multiply by 1.0E-06
   - Pa s (pascal seconds), multiply by 1.0E-07

   To convert from centipoise to:
   - lb/ft s, multiply by 0.000672
   - micropoise, multiply by 10,000
   - poise, multiply by 0.01
   - Pa s (pascal seconds), multiply by 0.001

8. **Thermal Conductivity**
   To convert from W/m K to:
   - BTU/hr ft R, multiply by 0.5788
   - calorie/cm s K, multiply by 0.002388

9. **Enthalpy of Formation**
   To convert from kJ/mol to:
   - kcal/mol, multiply by 0.239

10. **Gibb's Free Energy of Formation**
    To convert from kJ/mol to:
    - kcal/mol, multiply by 0.239

Appendix B

COMPOUND INDEX BY FORMULA

Formula	Name	Synonym	Page
Ar	argon		61(Vol 3)
Br2	bromine		110(Vol 3)
CBrF3	bromotrifluoromethane		235(Vol 1)
CClF3	chlorotrifluoromethane	fluorocarbon-13	205(Vol 1)
CCl2F2	dichlorodifluoromethane	fluorocarbon-12	205(Vol 1)
CCl2O	phosgene		16(Vol 2)
CCl3F	trichlorofluoromethane	fluorocarbon-11	205(Vol 1)
CCl4	carbon tetrachloride		44(Vol 1)
CF4	tetrafluoromethane	fluorocarbon-14	205(Vol 1)
CO	carbon monoxide		1(Vol 3)
COS	carbonyl sulfide		90(Vol 3)
CO2	carbon dioxide		1(Vol 3)
CS2	carbon disulfide		206(Vol 2)
CHClF2	chlorodifluoromethane	fluorocarbon-21	215(Vol 1)
CHCl2F	dichlorofluoromethane	fluorocarbon-22	215(Vol 1)
CHCl3	chloroform	trichloromethane	44(Vol 1)
CHF3	trifluoromethane	fluorocarbon-23	225(Vol 1)
CHN	hydrogen cyanide		126(Vol 2)
CH2Cl2	methylene chloride	dichloromethane	44(Vol 1)
CH2O	formaldehyde		6(Vol 2)
CH2O2	formic acid		26(Vol 2)
CH3Br	methyl bromide		235(Vol 1)
CH3Cl	methyl chloride		44(Vol 1)
CH3NO2	nitromethane		136(Vol 2)
CH4	methane		1(Vol 1)
CH4O	methanol		74(Vol 1)
CH4S	methanethiol		206(Vol 2)
CH5N	methylamine		96(Vol 2)
C2Cl2F4	1,2-dichloro-1,1,2,2-tertafluoroethane	fluorocarbon-114	215(Vol 1)
C2Cl3F3	1,1,2-trichloro-1,2,2-trifluoroethane	fluorocarbon-113	215(Vol 1)
C2Cl4	perchloroethylene		54(Vol 1)
C2F6	hexafluoroethane	fluorocarbon-116	225(Vol 1)
C2HCl3	trichloroethylene		54(Vol 1)
C2HCl3O	chloral		16(Vol 2)
C2H2	acetylene	ethyne	24(Vol 1)
C2H2Cl2	vinylidene chloride		54(Vol 1)
C2H2Cl2	cis-1,2-dichloroethylene		195(Vol 1)
C2H2Cl2	trans-1,2-dichloroethylene		195(Vol 1)
C2H2Cl4	1,1,2,2-tertachloroethane		195(Vol 1)
C2H2F2	vinylidene fluoride		225(Vol 1)

C2H3Cl vinyl chloride....................................54(Vol 1)
C2H3ClO acetyl chloride...................................16(Vol 2)
C2H3Cl3 methyl chloroform.......1,1,1-trichloroethane..195(Vol 1)
C2H3F vinyl fluoride....................................225(Vol 1)
C2H3N acetonitrile......................................126(Vol 2)
C2H4 ethylene...............ethene.................14(Vol 1)
C2H4Br2 ethylene dibromide......1,2-dibromoethane.....235(Vol 1)
C2H4Cl2 ethylene dichloride.....1,2-dichloroethane.....64(Vol 1)
C2H4O ethylene oxide....................................104(Vol 1)
C2H4O acetaldehyde......................................6(Vol 2)
C2H4O2 acetic acid.......................................26(Vol 2)
C2H5Br ethyl bromide...........bromoethane............235(Vol 1)
C2H5Cl ethyl chloride..........chloroethane...........64(Vol 1)
C2H5NO2 nitroethane.......................................136(Vol 2)
C2H6 ethane..1(Vol 1)
C2H6O ethanol.................ethyl alcohol..........74(Vol 1)
C2H6O methyl ether......................................46(Vol 2)
C2H6O2 ethylene glycol...................................114(Vol 1)
C2H6S ethanethiol.......................................206(Vol 2)
C2H6S dimethyl sulfide..................................206(Vol 2)
C2H7N dimethylamine.....................................96(Vol 2)
C2H7N ethylamine..106(Vol 2)
C3H4 methyl acetylene........propyne................24(Vol 1)
C3H4 propadiene..............allene.................34(Vol 1)
C3H4O acrolein..16(Vol 2)
C3H4O2 acrylic acid......................................76(Vol 2)
C3H5ClO epichlorohydrin...................................104(Vol 1)
C3H5N propionitrile.....................................126(Vol 2)
C3H6 propylene...............propene................14(Vol 1)
C3H6 cyclopropane.......................................176(Vol 2)
C3H6Cl2 propylene dichloride.....1,2-dichloropropane....64(Vol 1)
C3H6O propylene oxide...................................104(Vol 1)
C3H6O allyl alcohol.....................................94(Vol 1)
C3H6O prionaldehyde.....................................6(Vol 2)
C3H6O acetone...36(Vol 2)
C3H6O2 propionic acid....................................26(Vol 2)
C3H6O2 methyl acetate....................................66(Vol 2)
C3H7Cl propyl chloride.........1-chloropropane........64(Vol 1)
C3H7NO2 1-nitropropane....................................136(Vol 2)
C3H7NO2 2-nitropropane....................................136(Vol 2)
C3H8 propane...1(Vol 1)
C3H8O propanol...............propyl alcohol.........74(Vol 1)
C3H8O isopropanol............isopropyl alcohol......84(Vol 1)
C3H8O2 propylene glycol........1,2-propylene glycol...135(Vol 1)
C3H8O3 glycerine..............glycerol..............135(Vol 1)
C3H9N trimethylamine....................................96(Vol 2)
C3H9N isopropylamine....................................116(Vol 2)
C4H4O furan...56(Vol 2)
C4H4O2 furfural..56(Vol 2)

C4H6	1-butyne		24(Vol 1)
C4H6	2-butyne		24(Vol 1)
C4H6	1,2-butadiene		34(Vol 1)
C4H6	1,3-butadiene		34(Vol 1)
C4H6O2	vinyl acetate		66(Vol 2)
C4H6O2	methyl acrylate		76(Vol 2)
C4H6O3	acetic anhydride		86(Vol 2)
C4H7N	butyronitrile		126(Vol 2)
C4H8	1-butene		14(Vol 1)
C4H8	trans 2-butene		14(Vol 1)
C4H8	cis 2-butene		14(Vol 1)
C4H8	isobutylene	2-methylpropene	175(Vol 1)
C4H8	cyclobutane		176(Vol 2)
C4H8O	butylene oxide	1,2-butylene oxide	104(Vol 1)
C4H8O	butyraldehyde		6(Vol 2)
C4H8O	methyl ethyl ketone		36(Vol 2)
C4H8O	tetrahydrofuran		56(Vol 2)
C4H8O2	butyric acid		26(Vol 2)
C4H8O2	dioxane		56(Vol 2)
C4H8O2	ethyl acetate		66(Vol 2)
C4H10	butane		1(Vol 1)
C4H10	isobutane	2-methylpropane	175(Vol 1)
C4H10O	butanol	butyl alcohol	74(Vol 1)
C4H10O	isobutyl alcohol		84(Vol 1)
C4H10O	sec-butyl alcohol		84(Vol 1)
C4H10O	tert-butyl alcohol		84(Vol 1)
C4H10O	ethyl ether		46(Vol 2)
C4H10O3	diethylene glycol		114(Vol 1)
C4H11N	diethylamine		106(Vol 2)
C4H11N	butylamine		116(Vol 2)
C5H5N	pyridine		146(Vol 2)
C5H8	isoprene	2-methyl-1,3-butadiene	175(Vol 1)
C5H8	cyclopentene		186(Vol 2)
C5H8O2	ethyl acrylate		76(Vol 2)
C5H8O2	methyl methacrylate		76(Vol 2)
C5H10	1-pentene	isopentene	165(Vol 1)
C5H10	cyclopentane		176(Vol 2)
C5H12	pentane		155(Vol 1)
C5H12	isopentane	2-methylbutane	175(Vol 1)
C5H12O	1-pentanol	1-amyl alcohol	94(Vol 1)
C6H5Br	bromobenzene		196(Vol 2)
C6H5Cl	chlorobenzene		196(Vol 2)
C6H5F	fluorobenzene		196(Vol 2)
C6H6	benzene		156(Vol 2)
C6H7N	aniline		146(Vol 2)
C6H10	cyclohexene		186(Vol 2)
C6H10O3	propionic anhydride		86(Vol 2)
C6H12	1-hexene		165(Vol 1)
C6H12	cyclohexane		176(Vol 2)

C6H12 methyl cyclopentane..............................159(Vol 3)
C6H14 hexane..............................155(Vol 1)
C6H14 2-methylpentane.........isohexane.............185(Vol 1)
C6H14O 1-hexanol..............1-hexyl alcohol.......94(Vol 1)
C6H14O propyl ether..............................46(Vol 2)
C6H14O3 dipropylene glycol..............................135(Vol 1)
C6H14O4 triethylene gylcol..............................114(Vol 1)
C6H15N triethylamine..............................106(Vol 2)
C6H15N diisopropylamine..............................116(Vol 2)
C7H7Cl benzyl chloride..............................196(Vol 2)
C7H8 toluene..............................166(Vol 2)
C7H14 1-heptene..............................165(Vol 1)
C7H14 ethyl cyclopentane..............................159(Vol 3)
C7H14 methyl cyclohexane..............................169(Vol 3)
C7H16 heptane..............................155(Vol 1)
C7H16 2-methylhexane..............................185(Vol 1)
C7H16O 1-heptanol..............1-heptyl alcohol......94(Vol 1)
C8H8 styrene..............................186(Vol 2)
C8H10 ethylbenzene..............................156(Vol 2)
C8H10 m-xylene..............................166(Vol 2)
C8H10 o-xylene..............................166(Vol 2)
C8H10 p-xylene..............................166(Vol 2)
C8H12 cyclooctadiene..............................186(Vol 2)
C8H14O3 butyric anhydride..............................86(Vol 2)
C8H16 1-octene..............................165(Vol 1)
C8H16 propyl cyclopentane..............................159(Vol 3)
C8H16 ethyl cyclohexane..............................169(Vol 3)
C8H18 octane..............................155(Vol 1)
C8H18 isooctane..............2,2,4-trimethylpentane.185(Vol 1)
C8H18 2-methylheptane..............................185(Vol 1)
C8H18O butyl ether..............................46(Vol 2)
C8H19N dibutylamine..............................116(Vol 2)
C9H12 propylbenzene..............................156(Vol 2)
C9H12 cumene..............................156(Vol 2)
C9H18 propyl cyclohexane..............................169(Vol 3)
C10H8 naphthelene..............................209(Vol 3)
C10H14 butyl benzene..............................179(Vol 3)
C10H18 cis-decahydronaphthelene..............................209(Vol 3)
C10H18 trans-decahydronaphthelene..............................209(Vol 3)
C10H20 decene..............................139(Vol 3)
C10H22 decane..............................119(Vol 3)
C11H16 pentyl benzene..............................179(Vol 3)
C12H18 hexyl benzene..............................179(Vol 3)
C12H24 dodecene..............................139(Vol 3)
C12H26 dodecane..............................119(Vol 3)
C13H20 heptyl benzene..............................189(Vol 3)
C14H22 octyl benzene..............................189(Vol 3)
C14H28 tetradecene..............................139(Vol 3)
C14H30 tetradecane..............................119(Vol 3)

C15H24 nonyl benzene........189(Vol 3)
C16H26 decyl benzene........199(Vol 3)
C16H32 hexadecene........149(Vol 3)
C16H34 hexadecane........129(Vol 3)
C17H28 undecyl benzene........199(Vol 3)
C18H30 dodecyl benzene........199(Vol 3)
C18H36 octadecene........149(Vol 3)
C18H38 octadecane........129(Vol 3)
C20H40 eicosene........149(Vol 3)
C20H42 eicosane........129(Vol 3)
Cl2 chlorine........110(Vol 3)
F2 fluorine........110(Vol 3)
HBr hydrogen bromide........100(Vol 3)
HCl hydrogen chloride........100(Vol 3)
HF hydrogen fluoride........100(Vol 3)
HI hydrogen iodide........100(Vol 3)
H2 hydrogen........52(Vol 3)
H2O water........216(Vol 2)
H2S hydrogen sulfide........90(Vol 3)
He helium........52(Vol 3)
I2 iodine........110(Vol 3)
NH3 ammonia........42(Vol 3)
NO nitric oxide........70(Vol 3)
NO2 nitrogen dioxide........70(Vol 3)
N2 nitrogen........14(Vol 3)
N2O nitrous oxide........70(Vol 3)
Ne neon........61(Vol 3)
O2 oxygen........14(Vol 3)
O3 ozone........32(Vol 3)
SO2 sulfur dioxide........80(Vol 3)
SO3 sulfur trioxide........80(Vol 3)

Appendix C

COMPOUND INDEX BY NAME

Name	Synonym	Page
acetaldehyde		6(Vol 2)
acetic acid		26(Vol 2)
acetic anhydride		86(Vol 2)
acetone		36(Vol 2)
acetonitrile		126(Vol 2)
acetyl chloride		16(Vol 2)
acetylene	ethyne	24(Vol 1)
acrolein		16(Vol 2)
acrylic acid		76(Vol 2)
allyl alcohol		94(Vol 1)
ammonia		42(Vol 3)
aniline		146(Vol 2)
argon		61(Vol 3)
benzene		156(Vol 2)
benzyl chloride		196(Vol 2)
bromine		110(Vol 3)
bromobenzene		196(Vol 2)
bromotrifluoromethane		235(Vol 1)
1,2-butadiene		34(Vol 1)
1,3-butadiene		34(Vol 1)
butane		1(Vol 1)
butanol	butyl alcohol	74(Vol 1)
1-butene		14(Vol 1)
trans 2-butene		14(Vol 1)
cis 2-butene		14(Vol 1)
sec-butyl alcohol		84(Vol 1)
tert-butyl alcohol		84(Vol 1)
butylene oxide	1,2-butylene oxide	104(Vol 1)
butyl amine		116(Vol 2)
butyl benzene		179(Vol 3)
butyl ether		46(Vol 2)
1-butyne		24(Vol 1)
2-butyne		24(Vol 1)
butyraldehyde		6(Vol 2)
butyric acid		26(Vol 2)
butyric anhydride		86(Vol 2)
butyronitrile		126(Vol 2)
carbon dioxide		1(Vol 3)
carbon disulfide		206(Vol 2)
carbon monoxide		1(Vol 3)

carbon tetrachloride..........44(Vol 1)
carbonyl sulfide..........90(Vol 3)
chloral..........16(Vol 2)
chlorine..........110(Vol 3)
chlorobenzene..........196(Vol 2)
chlorodifluoromethane...fluorocarbon-21.......215(Vol 1)
chloroform..........trichloromethane......44(Vol 1)
chlorotrifluoromethane...fluorocarbon-13.......205(Vol 1)
cumene..........156(Vol 2)
cyclobutane..........176(Vol 2)
cyclohexane..........176(Vol 2)
cyclohexene..........186(Vol 2)
cyclooctadiene..........186(Vol 2)
cyclopentane..........176(Vol 2)
cyclopentene..........186(Vol 2)
cyclopropane..........176(Vol 2)
cis-decahydronaphthelene..........209(Vol 3)
trans-decahydronaphthelene..........209(Vol 3)
decane..........119(Vol 3)
decene..........139(Vol 3)
decyl benzene..........199(Vol 3)
dibutylamine..........116(Vol 2)
dichlorodifluoromethane..fluorocarbon-12........205(Vol 1)
cis-1,2-dichloroethylene..........195(Vol 1)
trans-1,2-dichloroethylene..........195(Vol 1)
dichlorofluoromethane...fluorocarbon-22.......215(Vol 1)
1,2-dichloro-1,1,
 2,2-tertafluoroethane...fluorocarbon-114......215(Vol 1)
diethylamine..........106(Vol 2)
diethylene glycol..........114(Vol 1)
diisopropylamine..........116(Vol 2)
dimethyl sulfide..........206(Vol 2)
dimethylamine..........96(Vol 2)
dioxane..........56(Vol 2)
dipropylene glycol..........135(Vol 1)
dodecane..........119(Vol 3)
dodecene..........139(Vol 3)
dodecyl benzene..........199(Vol 3)
eicosane..........129(Vol 3)
eicosene..........149(Vol 3)
epichlorohydrin..........104(Vol 1)
ethane..........1(Vol 1)
ethanethiol..........206(Vol 2)
ethanol..........ethyl alcohol.........74(Vol 1)
ethyl acetate..........66(Vol 2)
ethyl acrylate..........76(Vol 2)
ethyl amine..........106(Vol 2)
ethyl benzene..........156(Vol 2)
ethyl bromide...........bromoethane...........235(Vol 1)

ethyl chloride..........chloroethane..........64(Vol 1)
ethyl cyclohexane..............................169(Vol 3)
ethyl cyclopentane.............................159(Vol 3)
ethyl ether....................................46(Vol 2)
ethylene................ethene.................14(Vol 1)
ethylene dibromide.......1,2-dibromoethane.....235(Vol 1)
ethylene dichloride......1,2-dichloroethane....64(Vol 1)
ethylene glycol................................114(Vol 1)
ethylene oxide.................................104(Vol 1)
fluorine.......................................110(Vol 3)
fluorobenzene..................................196(Vol 2)
formaldehyde...................................6(Vol 2)
formic acid....................................26(Vol 2)
furan..56(Vol 2)
furfural.......................................56(Vol 2)
glycerine...............glycerol...............135(Vol 1)
helium...52(Vol 3)
heptane..155(Vol 1)
1-heptanol..............1-heptyl alcohol.......94(Vol 1)
1-heptene......................................165(Vol 1)
heptyl benzene.................................189(Vol 3)
hexadecane.....................................129(Vol 3)
hexadecene.....................................149(Vol 3)
hexafluoroethane........fluorocarbon-116.......225(Vol 1)
hexane...155(Vol 1)
1-hexanol...............1-hexyl alcohol........94(Vol 1)
1-hexene.......................................165(Vol 1)
hexyl benzene..................................179(Vol 3)
hydrogen.......................................52(Vol 3)
hydrogen bromide...............................100(Vol 3)
hydrogen chloride..............................100(Vol 3)
hydrogen cyanide...............................126(Vol 2)
hydrogen fluoride..............................100(Vol 3)
hydrogen iodide................................100(Vol 3)
hydrogen sulfide...............................90(Vol 3)
iodine...110(Vol 3)
isobutane...............2-methylpropane........175(Vol 1)
isobutyl alcohol...............................84(Vol 1)
isobutylene.............2-methylpropene........175(Vol 1)
isooctane...............2,2,4-trimethylpentane.185(Vol 1)
isopentane..............2-methylbutane.........175(Vol 1)
isoprene................2-methyl-1,3-butadiene.175(Vol 1)
isopropanol.............isopropyl alcohol......84(Vol 1)
isopropyl amine................................116(Vol 2)
methane..1(Vol 1)
methanethiol...................................206(Vol 2)
methanol.......................................74(Vol 1)
methyl acetate.................................66(Vol 2)
methyl acetylene........propyne................24(Vol 1)

methyl acrylate..........76(Vol 2)
methyl amine..........96(Vol 2)
methyl bromide..........235(Vol 1)
methyl chloride..........44(Vol 1)
methyl chloroform.......1,1,1-trichloroethane..195(Vol 1)
methyl cyclohexane..........169(Vol 3)
methyl cyclopentane..........159(Vol 3)
methyl ether..........46(Vol 2)
methyl ethyl ketone..........36(Vol 2)
methyl methacrylate..........76(Vol 2)
methylene chloride......dichloromethane........44(Vol 1)
2-methylheptane..........185(Vol 1)
2-methylhexane..........185(Vol 1)
2-methylpentane.........isohexane.............185(Vol 1)
naphthelene..........209(Vol 3)
neon..........61(Vol 3)
nitrogen..........14(Vol 3)
nitrogen dioxide..........70(Vol 3)
nitric oxide..........70(Vol 3)
nitroethane..........136(Vol 2)
nitromethane..........136(Vol 2)
1-nitropropane..........136(Vol 2)
2-nitropropane..........136(Vol 2)
nitrous oxide..........70(Vol 3)
nonyl benzene..........189(Vol 3)
octadecane..........129(Vol 3)
octadecene..........149(Vol 3)
octane..........155(Vol 1)
1-octene..........165(Vol 1)
octyl benzene..........189(Vol 3)
oxygen..........14(Vol 3)
ozone..........32(Vol 3)
pentane..........155(Vol 1)
1-pentanol..............1-amyl alcohol........94(Vol 1)
1-pentene...............isopentene............165(Vol 1)
pentyl benzene..........179(Vol 3)
perchloroethylene..........54(Vol 1)
phosgene..........16(Vol 2)
prionaldehyde..........6(Vol 2)
propadiene..............allene................34(Vol 1)
propane..........1(Vol 1)
propanol................propyl alcohol........74(Vol 1)
propionic acid..........26(Vol 2)
propionic anhydride..........86(Vol 2)
propionitrile..........126(Vol 2)
propyl benzene..........156(Vol 2)
propyl chloride.........1-chloropropane.......64(Vol 1)
propyl cyclohexane..........169(Vol 3)
propyl cyclopentane..........159(Vol 3)

propyl ether.................................46(Vol 2)
propylene...............propene...............14(Vol 1)
propylene dichloride.....1,2-dichloropropane....64(Vol 1)
propylene glycol........1,2-propylene glycol...135(Vol 1)
propylene oxide...............................104(Vol 1)
pyridine......................................146(Vol 2)
styrene.......................................186(Vol 2)
sulfur dioxide................................80(Vol 3)
sulfur trioxide...............................80(Vol 3)
1,1,2,2-tertachloroethane.....................195(Vol 1)
tetradecane...................................119(Vol 3)
tetradecene...................................139(Vol 3)
tetrafluoromethane......fluorocarbon-14.......205(Vol 1)
tetrahydrofuran...............................56(Vol 2)
toluene.......................................166(Vol 2)
trichloroethylene.............................54(Vol 1)
trichlorofluoromethane...fluorocarbon-11.......205(Vol 1)
1,1,2-trichloro-1,2,
2-trifluoroethane......fluorocarbon-113......215(Vol 1)
triethylamine.................................106(Vol 2)
triethylene gylcol............................114(Vol 1)
trifluoromethane........fluorocarbon-23.......225(Vol 1)
trimethylamine................................96(Vol 2)
undecyl benzene...............................199(Vol 3)
vinyl acetate.................................66(Vol 2)
vinyl chloride................................54(Vol 1)
vinyl fluoride................................225(Vol 1)
vinylidene chloride...........................54(Vol 1)
vinylidene fluoride...........................225(Vol 1)
m-xylene......................................166(Vol 2)
o-xylene......................................166(Vol 2)
p-xylene......................................166(Vol 2)
water...216(Vol 2)

3 9001 03237 8690

Physical Properties of Hydrocarbons

And Other Chemicals

VOLUME 3

This newest volume in the *Physical Properties of Hydrocarbons* series provides indispensable data on nitrogen, oxygen, air, ammonia, hydrogen, helium, other inorganics, alkanes, alkenes, naphthenes, and aromatics. Extensive data derived from the literature and detailed information not available elsewhere are combined in one source to provide the working engineer with enormous savings in time and effort.

Data on critical properties, vapor pressure, heat of vaporization, density, surface tension, heat capacity, viscosity, thermal conductivity, enthalpy of formation, and Gibb's free energy of formation are presented in graphical form for each compound. Wherever possible, data have been extended over a wide temperature range. Water solubility, lower explosion limit, and upper explosion limit are included in the tables to assist environmental and safety engineers.

The SI and metric units are used for all properties except vapor pressure. Each graph displays a conversion factor providing English units. A comprehensive index makes all of this vast data readily accessible by formula and compound name.

This one handy reference provides chemical, environmental, and safety engineers with quick and easy access to vital physical property data needed for production and process design calculations.

About the Authors

R. W. Gallant is the vice-president of Texas Operations for Dow Chemical Company, Freeport, Texas. Previously, he was general manager of Hydrocarbons and Energy at Dow's Louisiana Division. He received his B.S. degree in chemical engineering from the University of Florida.

Carl L. Yaws, Ph.D., is professor of chemical engineering at Lamar University. He earned his B.S. degree in chemical engineering from Texas A&I University and his Ph.D. from the University of Houston. He is a registered professional engineer, holds several patents, and is the author of *Thermodynamic and Physical Property Data.*

Physical Properties of Hydrocarbons, Volume 1, Second Edition

R. W. Gallant and Carl L. Yaws

Complete working information is given on the paraffinic hydrocarbons, halogenated hydrocarbons, and several oxygenated hydrocarbons. Product #5067

Physical Properties of Hydrocarbons, Volume 2, Third Edition

R. W. Gallant and Carl L. Yaws

Complete working information is given on the oxygenated hydrocarbons, nitrogen-containing hydrocarbons, aromatics, cyclic hydrocarbons, and sulfur-containing hydrocarbons. Product #5175

PRODUCT #5176
50000
9 780884 151760
ISBN 0-88415-176-X

Gulf Publishing Company
Book Division
P.O. Box 2608
Houston, Texas 77252-2608